AD NUMBER
AD504599
CLASSIFICATION CHANGES
TO: **UNCLASSIFIED**
FROM: **CONFIDENTIAL**
LIMITATION CHANGES
TO: **Approved for public release; distribution is unlimited.**
FROM: **Distribution authorized to U.S. Gov't. agencies and their contractors; Critical Technology; APR 1969. Other requests shall be referred to Air Force Armament Laboratory, Attn: ATWB, Eglin AFB, FL32542. This document contains export-controlled technical data.**
AUTHORITY
USADTC ltr, 5 Apr 1979; USADTC ltr, 5 Apr 1979

SECURITY

MARKING

The classified or limited status of this report applies to each page, unless otherwise marked.
Separate page printouts MUST be marked accordingly.

AD504599

CONFIDENTIAL

AFATL-TR-69-59

DESIGN AND DEVELOPMENT OF VERY LONG DELAY FUZE (U)

W. L. Aschenbeck
Honeywell Inc.

TECHNICAL REPORT AFATL-TR-69-59

APRIL 1969

This material contains information affecting the national defense of the United States within the meaning of the Espionage Laws (Title 18, U.S.C., sections 793 and 794), the transmission or revelation of which in any manner to an unauthorized person is prohibited by law.

OCT 1 1969

In addition to security requirements which must be met, this document is subject to special export controls and each transmittal to foreign governments or foreign nationals may be made only with prior approval of the Air Force Armament Laboratory (ATWB), Eglin AFB, Florida 32542.

AIR FORCE ARMAMENT LABORATORY

AIR FORCE SYSTEMS COMMAND • UNITED STATES AIR FORCE

EGLIN AIR FORCE BASE, FLORIDA

GROUP-4
DOWNGRADED AT 3 YEAR INTERVALS;
DECLASSIFIED AFTER 12 YEARS.

CONFIDENTIAL

CONFIDENTIAL

DESIGN AND DEVELOPMENT OF VERY LONG DELAY FUZE (U)

W. L. Aschenbeck

CONFIDENTIAL

FOREWORD

(U) This final report describes the fuze development work performed by the Honeywell Ordnance Division during the period March 1968 through December 1968 under contract F08635-68-C-0068 with the Air Force Armament Laboratory (AFATL), Eglin Air Force Base, Florida 32542. The program was conducted at the Honeywell Ordnance Division Headquarters at 600 Second Street North, Hopkins, Minnesota 55343. The program, which resulted in the development of a design for a Very Long Delay Fuze (VLDF), also included the fabrication of 20 deliverable flight test models of a ground-settable VLDF, and the fabrication of one feasibility model of a cockpit-settable VLDF, together with the necessary test and monitoring equipment. The models and test equipment were delivered to AFATL (ATWB), Eglin Air Force Base, Florida.

(U) The program was conducted under the technical direction of Captain George C. German, AFATL (ATWB), Eglin Air Force Base, Florida 32542.

(U) The delivered models of the fuze are classified Confidential as are all data defining or relating to the timer accuracy, estimates of reliability, the maximum time data, and laboratory and field tests results. This report does not contain classified information extracted from other classified documents.

(U) Information in this report is embargoed under the Department of State International Traffic in Arms Regulations. This report may be released to foreign governments by departments or agencies of the U. S. Government subject to approval of the Air Force Armament Laboratory (ATWB), Eglin AFB, Florida 32542, or higher authority within the Department of the Air Force. Private individuals or firms require a Department of State export license.

(U) This technical report has been reviewed and is approved.

John H Hobaugh
JOHN H. HOBAUGH, Colonel, USAF
Chief, Weapons Division

CONFIDENTIAL ABSTRACT

(C) A design was developed to demonstrate the feasibility of a ground-settable Very Long Delay Fuze for use in air-delivered bombs and mines with standard fuze wells, and which is capable of eventing the munition at a preselected time which is selected from a range of event times. The delay range extends from 20 seconds to 30 days after impact, and the delay is selected before take-off. Laboratory tests of complete developmental models demonstrated that the fuze was capable of functioning properly after an impact environment characteristic of the delivery profile of a 750-pound general purpose bomb. Safety features were developed to comply with MIL-STD-1316. The explosive train was developed to meet the requirements of MIL-STD-331, Test 115. The fuze is powered by a reserve ammonia battery (output of 2.8 to 4.5 volts). A fuze model similar in physical and functional characteristics to the ground-settable fuze was developed to demonstrate the feasibility of using the fuze with an AN/AWW-4 Fuze Function Control Set for the purpose of selecting an event time from the cockpit. The cockpit-settable capability was demonstrated successfully, along with the use of complementary metal-oxide semiconductor (CMOS) circuits for timing functions. It was shown that the use of CMOS circuits would provide a fuze of greater accuracy than could be achieved through the use of E-cells.

(The reverse of this page is blank)

TABLE OF CONTENTS

TABLE OF CONTENTS (Concluded)

LIST OF FIGURES

LIST OF FIGURES (Concluded)

LIST OF TABLES

(The reverse of this page is blank)

SECTION I

INTRODUCTION

(C) The object of the work performed was the development of advanced flight test models of a ground-settable Very Long Delay Fuze (VLDF) and a feasibility model of a cockpit-settable VLDF. The VLDF was designed for use in air-delivered bombs and mines intended for area denial applications. The VLDF is capable of delaying the detonation of a bomb or mine from 20 seconds to 30 days from the time of impact.

(U) The development work performed was designated Phase II of a continuing VLDF development program. Phase I was initiated for the development of a Timer and a Setter.

SECTION II

REQUIREMENTS

(U) The Very Long Delay Fuze developed, as well as the ammonia battery power supply incorporated in the 20 deliverable models of the ground-settable fuze, was designed to meet the following requirements.

Ground-Settable Capability

(U) The ground-settable model of the fuze shall have the capability for selecting a 30-second or long-delay burst.

Cockpit-Settable Capability

(U) The cockpit-settable model of the fuze shall have the capability of being set to any one of the long-delay burst options on the ground. During delivery, the pilot shall be capable of overriding the delay period selected on the ground and resetting the fuze for a 30-second delay burst.

Approach

(U) The fuze shall contain all of the components and subassemblies necessary to accomplish the delayed eventing of high- and low-drag bombs and mines. The complete fuze shall consist of the following major components: setter, timer, power supply, safing and arming (S&A) device, safing and arming logic controls, dimple motor (to simulate detonator), initiation device and lanyard (or electrical cable, if applicable), anti-withdrawal device, and container. This work shall be accomplished utilizing work previously accomplished in Phase I of the Very Long Delay Fuze development program.

Survivability - Shock

(U) The fuze shall be designed, developed, and packaged so that an initiated fuze will survive, and be capable of performing all required functions, after a 20,000-g shock (with a duration of from 2 to 4 milliseconds) in the axial directions, and a 25-fps steel-on-steel impact in the two transverse directions.

Production Techniques

(U) The fuze shall be designed to be compatible with current fabrication and assembly-line production techniques.

Reliability

(U) The fuze design shall be reviewed to ensure that the final design takes into consideration the requirements of MIL-STD-785. The reliability of the fully developed fuze will be at least 95 percent at a confidence level of 90 percent under operational conditions. The components to be designed in this effort shall be designed so that the ultimate reliability goal can be met or surpassed in a future effort.

Safety

(U) The fuze shall be designed to comply with MIL-STD-1316.

Isolation of Power Supply

(U) The design of the fuze shall incorporate features to isolate the battery power supply voltage from the electronic circuits until initiation on bomb release.

Environment Sensor

(U) A flight environment sensor shall be included to enable arming subsequent to a valid release and to preclude arming as a result of an inadvertent release such as during take-off or landing.

Separation Timer

(U) The fuze shall include a timer to ensure that safe separation is achieved prior to arming.

Detonator Safety

(U) The safing and arming (S&A) mechanism shall employ the out-of-line detonator or interrupter shutter principle. It shall be designed for compliance with MIL-STD-331, Test 115.

Anti-tamper Device

(U) The fuze shall include an anti-tamper device to prevent withdrawal of the fuze after arming.

Indication of Arming

(U) The S&A mechanism shall be designed so that the "arm" or "safe" condition of the fuze can be readily established by external examination prior to installation of the fuze into the bomb.

Safing Pin

(U) The fuze shall possess an external safing pin which, when in place, shall prevent fuze functioning by preventing alignment of the detonator and booster. The safing pin shall be designed to preclude partial or improper insertion. It is intended that the safing pin will remain in place

until installation of the lanyard. A suitable red flag shall be affixed to the safing pin.

Battery Firing Device and Lanyard

(U) The ground-settable fuze shall incorporate a battery firing device that prevents alignment of the detonator and booster prior to bomb release. A lanyard shall be used to activate the battery firing device.

Cockpit Selector

(U) The initiation device of the cockpit-settable fuze shall be compatible with the USN Fuze Function Control Set (AN/AWW-4), and shall utilize a USN-type initiation cable compatible with the AN/AWW-4.

Setter

(U) The setter shall be designed such that the burst option (30-second or long-delay burst) and delay times may be set externally using a screw-driver or other simple tool. An indication of the function and delay time so selected shall be provided on the face of the fuze.

Power Supply

(U) A power supply shall be provided to power the timer and the S&A mechanism. It shall also provide power to the other electronics necessary to meet the complete fuzing requirements.

Timer Capacity and Accuracy

(C) The timer, in conjunction with the setter, shall provide delay times from 30 seconds to 30 days. At least 24 discrete delay times shall be provided within this range. A timer accuracy of ±20 percent will be provided.

Shelf Life

(U) The fuze shall be designed for a 10-year shelf life.

Environmental Resistance

(U) The fuze shall be designed so the final fuze design, to be developed in future phases, will be capable of withstanding the following MIL-STD-331 tests for fuzes:

MIL-STD-331	Test 101, Jolt
MIL-STD-331	Test 102, Jumble
MIL-STD-331	Test 103, Forty-Foot Drop
MIL-STD-331	Test 104, Transportation Vibration
MIL-STD-331	Test 105, Temperature-Humidity
MIL-STD-331	Test 107, Salt Spray (Fog)
MIL-STD-331	Test 201, Jettison (Aircraft Safe Drop - Fuzes)
MIL-STD-331	Test 206, Accidental Release (Low Altitude, Hard Surface)
MIL-STD-331	Test 115, Static Detonator Safety
MIL-STD-331	Test 205, Jettison (Aircraft Safe Drop-Fuze System)
MIL-STD-331	Test 108, (modified; see note below)
MIL-STD-331	Test 110, Fungus Resistance
MIL-STD-331	Test 111, Five-Foot Drop
MIL-STD-331	Test 112, Extreme Temperature Storage
MIL-STD-331	Test 113, Thermal Shock
MIL-STD-331	Test 114, Rough Handling (Package)
MIL-STD-210	Climatic Extremes for Military Equipment
MIL-STD-810A	Environmental Test Methods for Aerospace and Ground Equipment

(U) Note: In conducting MIL-STD-331, Test 108, the fuze shall be immersed in water to a maximum depth of 1 foot at atmospheric pressure, and the test shall be conducted at 70°F. The test for compliance with MIL-STD-810A shall not include any of the tests required by any other military standards listed.

Dissimilar Metals

(U) Unless suitably protected against electrolytic corrosion, dissimilar metals shall not be used in intimate contact with each other. Nonpermissible couples as defined in MIL-STD-171 shall not be used.

Approach Angle

(U) The fuze shall meet performance specifications for all angles of approach from 5° to 90°F.

Vertical Velocity

(U) The fuze shall meet performance specifications for all vertical velocities from 100 to 1100 feet per second.

Electromagnetic Radiation

(U) The fuze shall be functionally immune to the electromagnetic radiation which may be encountered during handling and aircraft carriage. Compliance with MIL-STD-826A is required.

Housing, Compatibility

(U) The fuze shall be suitable for use with munitions containing the standard fuze well and internal plumbing.

Initiation

(U) Initiation of the ground-settable fuze shall be accomplished by withdrawal of a lanyard through the internal plumbing of either high- or low-drag bombs or land mines. Initiation of the cockpit-settable fuze shall be compatible with the USN Fuze Function Control Set AN/AWW-4 and the associated bomb/aircraft cable assembly.

Aircraft Carriage

(U) The fuze shall meet all performance specifications, after being subjected to the normal aerodynamic effects associated with external carriage by current fighter/bomber and bomber aircraft at altitudes from 100 feet to 60,000 feet and at speeds up to Mach 1.5 when released in the proper configuration with the required lanyard extraction force, and when released within the specified approach angle and vertical velocity limits.

Slow Cook-off

(U) If the fuze incorporates explosive components to align the explosive train, the S&A mechanism temperature shall be raised 6°F per hour until the detonator fires. When the detonator fires, it shall fire out-of-line.

Structural Integrity

(U) The fuze body and structure shall be such as to minimize the possibility of activation of boosters or bomb high-explosive loading by impact crushing of the fuze during safe jettison.

Minimum Release Speed

(U) The fuze shall perform its intended function after being released at a minimum speed of 300 knots.

Minimum Drop Time

(U) The fuze shall perform its intended function after experiencing drop for a duration of at least 4 seconds.

Acceptance

(U) The deliverable models shall be tested to MIL-STD-331, Tests 104, 105, 112, and 113. The deliverable models shall also be subjected to appropriate shock tests.

SECTION III

DELIVERED ITEMS AND SERVICES

(U) In accordance with the requirements for the advanced development (Phase II) of a Very Long Delay Fuze, the following items and services were provided to the Air Force for design evaluation and Air Force qualification tests:

- Twenty ground-settable delay-burst option fuzes (see Figure 1)
- One cockpit-settable delay-burst option fuze, complete with special test equipment required for evaluation testing (see Figure 2)
- Field engineering services for assistance in Air Force evaluation testing.
- One complete set of design documentation for the ground-settable fuze, including:
    - CEI Detail Specification, Part I
    - Engineering data
    - Engineering drawings
    - Engineering parts lists
    - Explosive Ordnance Disposal Procedures
    - Packaging, Handling, and Transportability Plan
    - Explosive Components Technical Data Sheets
    - Still photo coverage, and
    - Program status reports.

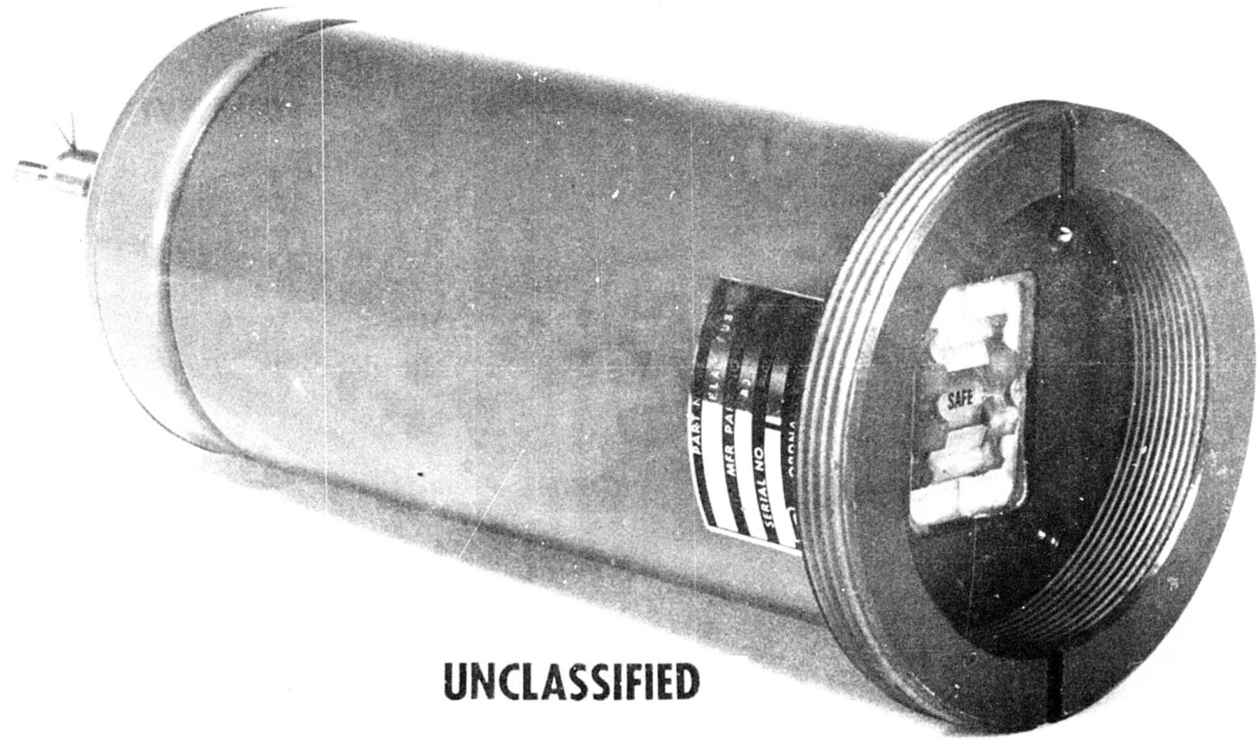
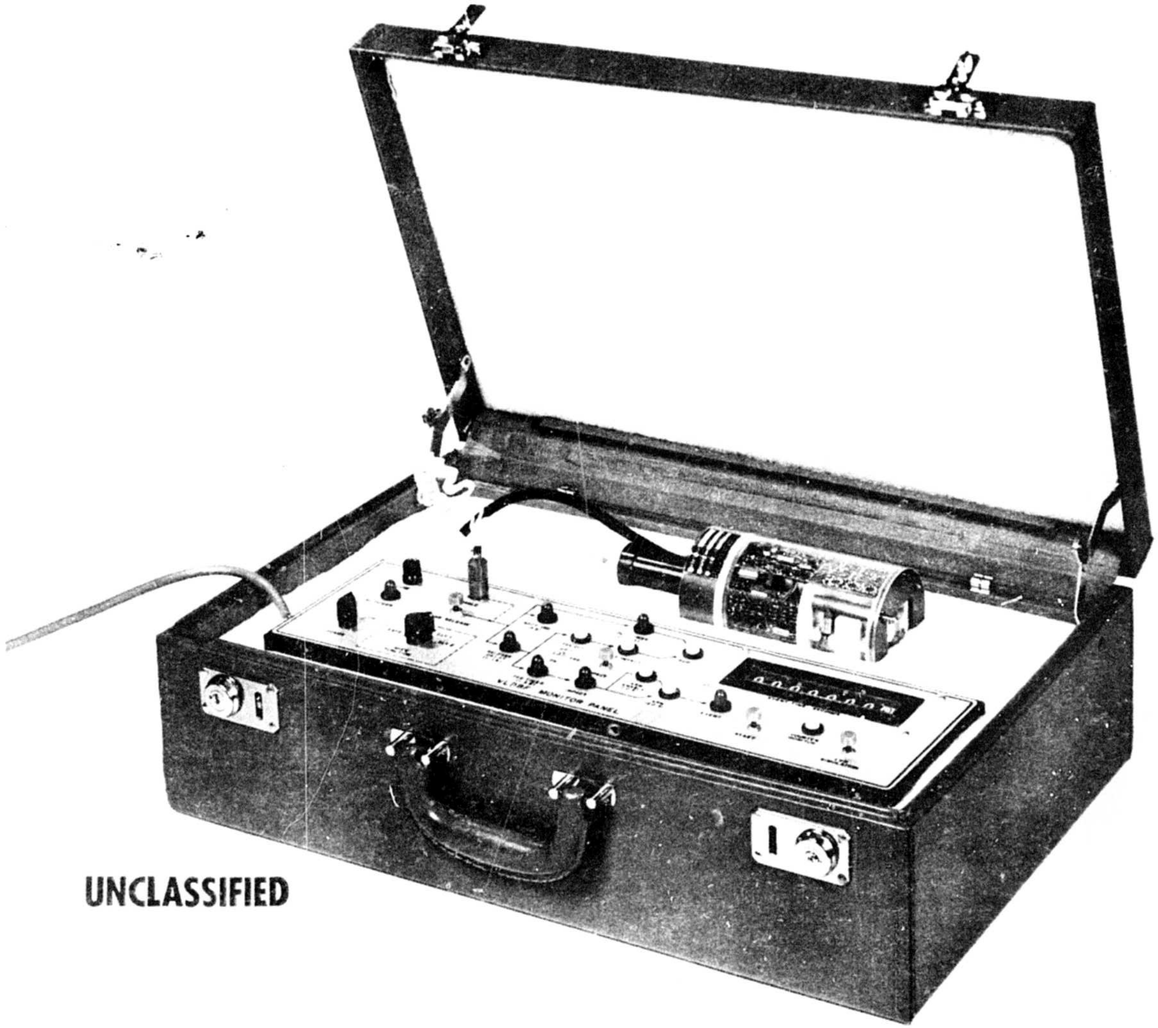


Figure 1. Very Long Delay Fuze, Ground-Settable Model



UNCLASSIFIED

Figure 2. Very Long Delay Fuze, Cockpit Settable Model (Including Special Test Equipment)

SECTION IV

DEVELOPMENT APPROACH

(C) The Very Long Delay Fuze design developed during Phase II was based on the setter and timer designs developed in Phase I. Because of the 10-year shelf life requirement, the requirement of a 30-day active life for the power supply, and the wide range of operating temperature specified, the power supply chosen for the VLDF was an ammonia battery.

(U) With the setter and timer concepts established and the power supply chosen, work was initiated on the definition of fuze logic. The fuze logic was designed to meet the safety requirements of MIL-STD-1316 and the logistical requirements of the Air Force. The definition of fuze logic was followed by the development of the electronic and mechanical designs of the fuze.

(U) The fuze electronics were designed using the Bissett-Berman E-cells for the main event timer, the backup timer, and the 140-second timer. Preliminary designs for each electronic circuit were tested for functional capability and compatibility with the temperature, vibration, and shock, as well as for compatibility with the voltage characteristics of the ammonia battery.

(U) The materials specified for mechanical parts were chosen for compatibility with high production techniques. To the greatest extent possible, materials compatible with high production molding techniques were specified for use in fabricating applicable components of the setter and the S&A mechanism. The materials for the fuze container were chosen on the basis of strength and production economy.

(U) The assembly and packaging designs were developed to permit a complete cycle of testing during assembly without jeopardizing the integrity of the final assembly. With this approach, individual subassemblies are tested to ensure compatibility with voltage and temperature requirements, and verify individual component capabilities. The packaging design provides for the encapsulation of the complete fuze in high-strength epoxy within a thick-walled steel container. By encapsulating the fuze in two separate steps, a complete evaluation of the encapsulated electronic circuits is possible before final assembly. A test connector was included in the Phase II flight test models so the fuze event could be monitored electronically after recovery from the test vehicle.

(U) Initial tests consisted of complete evaluations of individual models of electronic circuits and mechanical components and subassemblies. Mechanical components of the first preliminary model were subjected to vibration and shock tests. The electronics were evaluated against the temperature and voltage ranges specified.

(U) The results of the tests of the first models provided the basis for the design of a group of second preliminary models. These models included all components specified for the complete fuze and were essentially identical to the final deliverable models. The second preliminary models were subjected to transportation vibration tests, aircraft vibration tests, shock tests, and water immersion tests.

(U) Further design refinements indicated by the results of testing the second preliminary models were incorporated in the deliverable models. All subassemblies used in the deliverable models were subjected to a detailed design evaluation.

(U) The cockpit-settable fuze, which is physically and functionally similar to the ground-settable fuze, was designed for ultimate use with the USN Fuze Function Control Set AN/AWW-4. Because the cockpit-settable

(U) Continued
fuze developed during Phase II was designed for concept evaluation in the laboratory, a replaceable primary battery was chosen. A complimentary metal-oxide semiconductor (CMOS) binary counter was used as the event timer. The cockpit settable fuze was supplied with the test equipment required for conducting a complete range of evaluation tests.

SECTION V
DESIGN DESCRIPTION

(U) Two versions of the Very Long Delay Fuze (VLDF) were developed, a flight test model of a ground-settable VLDF and a feasibility model of a cockpit-settable VLDF intended for use in laboratory testing and evaluation. With the exception of the override features of the cockpit-settable fuze to adapt it for use with the USN Fuze Function Control Set (AN/AWW-4), both versions are similar.

(U) The delivery profile for the VLDF is shown in Figure 3. The profile depicts the overall functional characteristics of both the ground-settable and cockpit-settable versions of the fuze. The operating sequence begins, when the bomb is released, with the initiation of the fuze battery. Once the battery is initiated, the fuze operating sequence will result either in a dud bomb or a fuze event at a preselected time after impact. The dud function is defined as "firing the detonator in the out-of-line position". The event function is defined as "firing the detonator when the explosive train is in line".

(C) The following fuze operating sequence is typical. The application of fuze power enables the flight environment sensor. If a true flight environment is sensed for an uninterrupted period of at least 1.5 seconds, an appropriate signal is transferred to the arming logic. If a proper flight environment is not sensed before impact, the fuze will dud at impact. An impact shock of at least 80 g's must be sensed by the impact sensor to start the arm enable timer and arm timer. Two independent timers, the 10-second arm enable timer and the 20-second arm timer, provide an arm enable signal at 10 seconds after impact and an arm signal at 20 seconds after impact. The fuze event time is measured from arming. The fuze can be set for 25 different event times, ranging from an event at arming to an event 30 days after arming.

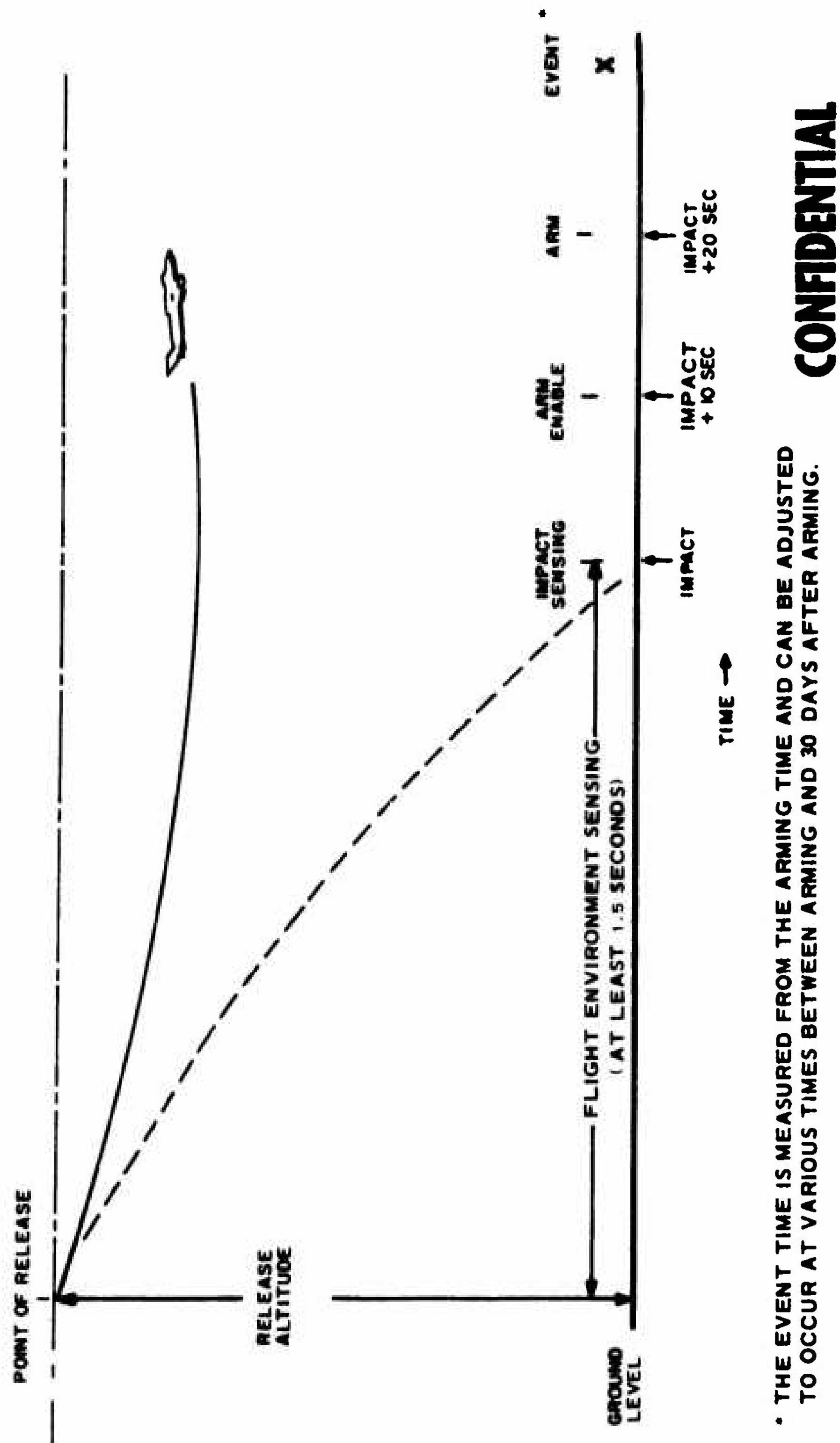


Figure 3. Very Long Delay Fuze Delivery Profile

(U) The design details of both versions of the Very Long Delay Fuze are described in this section.

A. GROUND-SETTABLE FUZE

(U) The overall design developed for the ground-settable model of the VLDF is illustrated in Figure 4. The major components of this design are shown in their order of assembly in Figure 5.

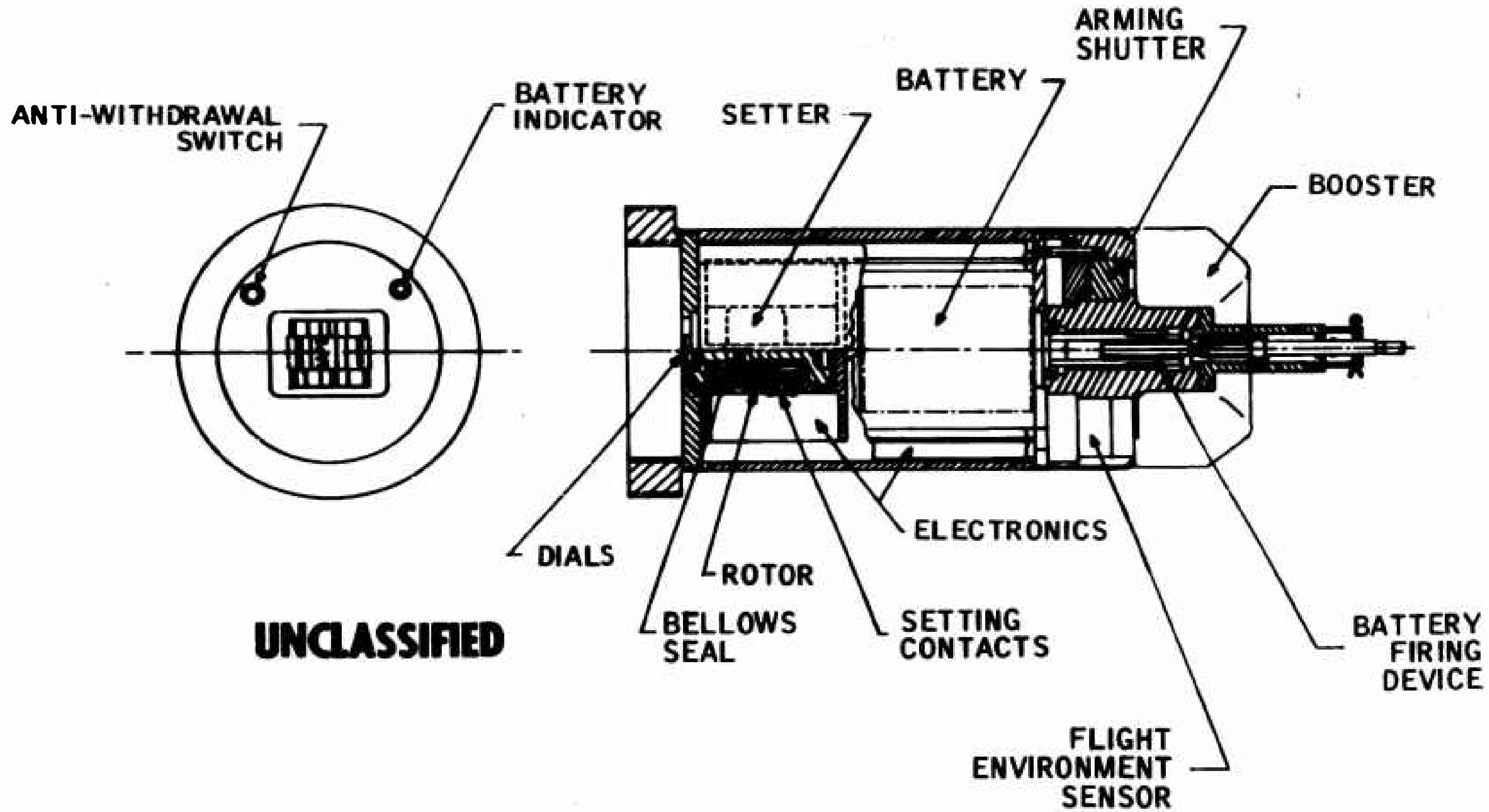
(U) All of the components shown in Figure 4, except the booster and the battery firing device, are potted and environmentally sealed within the container. As assembled, the dials and scales of the setter, the plunger of the anti-withdrawal switch, and the battery status indicator protrude through the front plate of the container. The battery firing device is threaded into the rear of the fuze, with an O-ring providing an environmental seal, and the booster (which was inert in the deliverable models) is assembled to the rear face of the fuze, over and around the battery firing device.

(U) The flight environmental sensors were not incorporated into the deliverable models, but were supplied as separate components to facilitate testing and evaluation. As designed, the flight environment sensor is part of the S&A mechanism assembly.

(U) The anti-withdrawal switches, although assembled into the deliverable models, were not electrically connected into the fuze circuit. This was done to prevent a fuze event when the fuze was removed from the test vehicle. Test points were provided so the operation of the anti-withdrawal switch could be monitored after the fuze was recovered from the test vehicle.

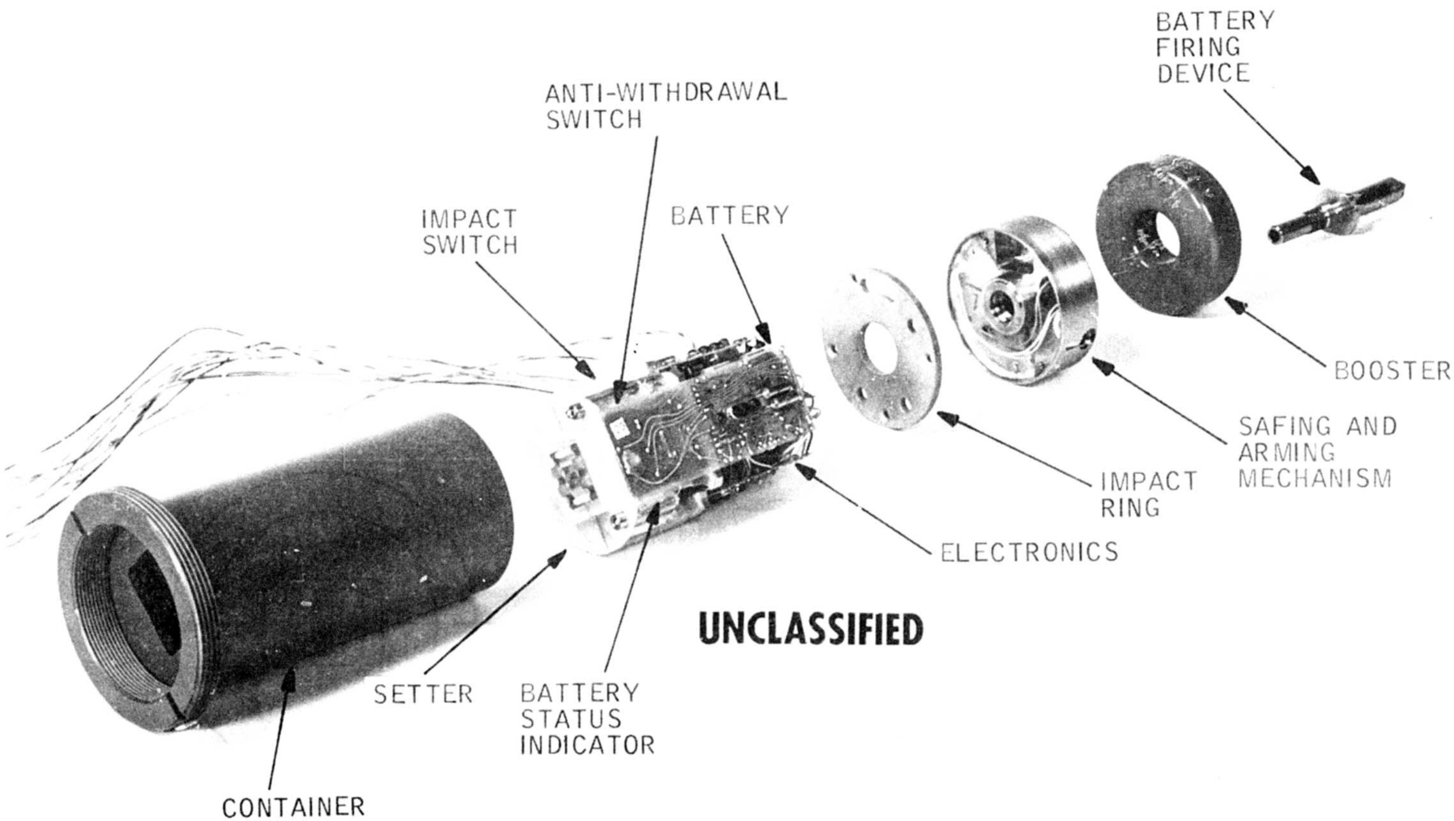
1. Functional Description

(U) The functions of the ground settable fuze are depicted in the block diagram of Figure 6. The operation of the fuze occurs in two phases, an



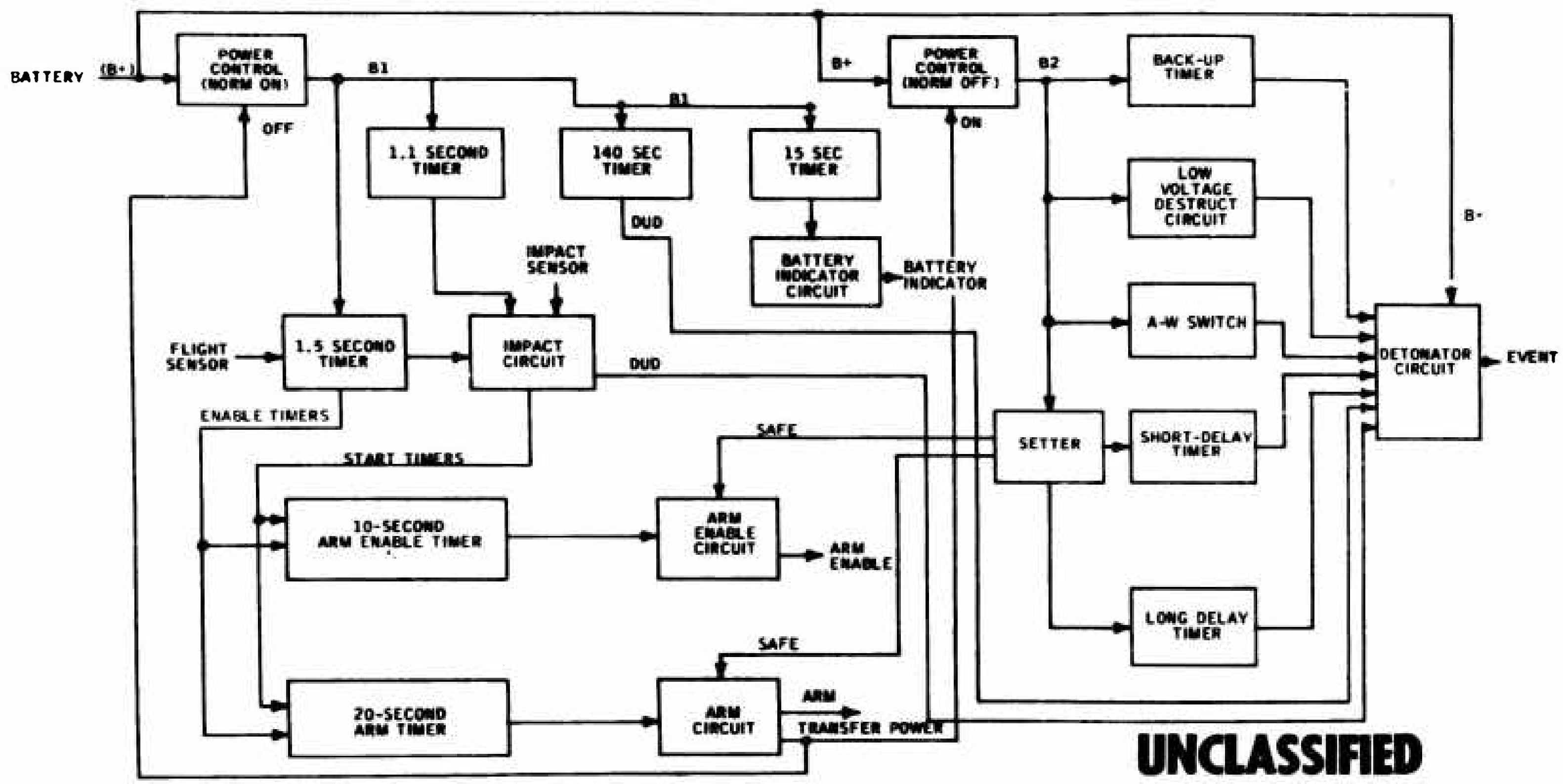
UNCLASSIFIED

Figure 4. Ground-Settable Fuze, Overall Design



UNCLASSIFIED

Figure 5. Very Long Delay Fuze, Ground-Settable Model, Major Components Shown in Order of Assembly



UNCLASSIFIED

Figure 6. Block Diagram, Ground-Settable Fuze

(U) Continued

arming cycle and an event cycle. Fuze power is conserved by disconnecting the arming circuits after the arming cycle is completed; at the same time, power is applied to the circuits which control the event cycle. The power transfer is accomplished by a squib switch in the power control circuit.

(U) The arming cycle is automatically started when the battery is initiated at bomb release. The battery output is applied to the power control circuit which, in turn, simultaneously supplies B1 power to four timers in the arming logic, the 1.1-second release delay timer, the 1.5-second timer, the 15-second timer, and the 140-second timer. These timers have the following functions:

- The 1.1-second timer inhibits the impact sensing function for the first 1.1 seconds after application of B1 power. Thus, the 1.1-second timer prevents impact circuit activation if a bomb is accidentally released from an aircraft on the ground. The 1.1-second timer also prevents the ejection force at bomb release from being interpreted by the fuze as the force resulting from impact.

- The 1.5-second timer provides an enabling signal that electrically enables the arm logic if a proper (free-fall) bomb flight is sensed for an uninterrupted period of at least 1.5 seconds (flight environment sensors were not included in deliverable methods).

- The 15-second timer delays an indication of battery initiation for 15 seconds, and thus prevents heavy current drain on the battery, when the battery indicator dimple motor fires, by permitting the energy required to fire the motor to be stored in a capacitor over a period of 15 seconds.

- The 140-second timer provides a signal which duds the fuze if arming is not experienced within 140 seconds from fuze initiation.

(U) Initiation of the arming timers is dependent on the proper sequential operation of the flight environment sensor and impact sensor. The flight environment sensor must be closed for an uninterrupted period of at least 1.5 seconds prior to impact. If impact occurs after the 1.1-second timer times out (1.1 seconds from release) but before a proper flight environment

(U) Continued
is sensed, the fuze will dud upon impact. When the proper flight environment has been sensed prior to impact, the dud feature in the impact circuit is disabled and the arming timers are enabled. The arm enable timer and arm timer are then able to start timing at impact. Fuze arming is directly dependent on two electrically and mechanically independent functions. In one function, the 10-second arm enable timer fires a dimple motor 10 seconds after impact, thus removing a gag rod from the S&A mechanism. In the other function, the 20-second arm timer initiates a piston actuator 20 seconds after impact, the action of which moves the S&A mechanism into the armed condition. The arm timer also initiates the power control circuit squib switch, turning off B1 power to the arm circuits and applying B2 power to the circuits which control the event cycle.

(C) The event time is preselected in the setter by using the dials which protrude through the front face of the fuze. Any one of 25 long-delay settings can be selected, ranging from 1 hour to 30 days. In addition, a short delay can be selected which provides an event approximately 20 seconds after impact.

(C) To provide maximum assurance that the fuze will event after a proper delivery (and thus significantly reduce the probability of unexpended munitions), a back-up timer and a low-voltage destruct circuit have been incorporated in the fuze. The back-up timer provides an event signal 30 days after release. The low-voltage destruct (LVD) circuit monitors the B2 voltage level. If the B2 voltage decreases below a preselected level, the LVD circuit produces an event signal. To prevent unfriendly forces from tampering with an armed bomb, an anti-withdrawal (A-W) switch has been incorporated (not active in the deliverable models). If an attempt is made to remove the fuze well closure of an armed bomb, the A-W switch will produce an event signal.

(U) When set to the SAFE position, the setter provides for maximum safety during handling and transportation of the fuze by disabling the arm enable and arming circuits. If the battery is activated and the arming

(U) Continued

requirements are properly satisfied during handling or transportation (a relatively remote possibility), the outputs of both arm timers will be shorted to ground when the setter is in the SAFE position. Furthermore (and this feature is especially significant if the fuze is accidentally initiated after installation in a bomb), the fuze safety circuits remain enabled when the setter selector switch is set to SAFE, and the detonator will fire in the out-of-line position, thus dudding the bomb.

2. Electronic Circuits

(U) A complete electrical schematic of the deliverable model of the ground-settable fuze is presented in Figure 7. The dashed enclosures in the schematic correspond to the functional blocks in Figure 6. The heavy solid lines define the components which were included on the various printed circuit boards and circuit modules (see illustration of packaging concept in Figure 8).

(U) Two concepts were utilized to implement timing functions. A programmable unijunction transistor (PUT) timer concept was used to provide the relatively short delays required in the arming logic. A capability for operation at low current levels and an insensitivity to input voltage variations were the primary reasons for selecting the PUT timer approach. The relatively long event-time delays were generated with coulometric timing devices (Bissett-Berman E-Cells).

(U) The PUT is a three-terminal semiconductor switching device. The terminals are designated anode, anode gate, and cathode. In the off condition the PUT presents a large impedance (approximately 10 megohms) between the anode and cathode terminals. The PUT is triggered into a conductive mode by raising the anode approximately 0.5 volt positive with respect to the anode gate. In the conducting mode, the anode-to-cathode impedance is reduced to less than 100 ohms.

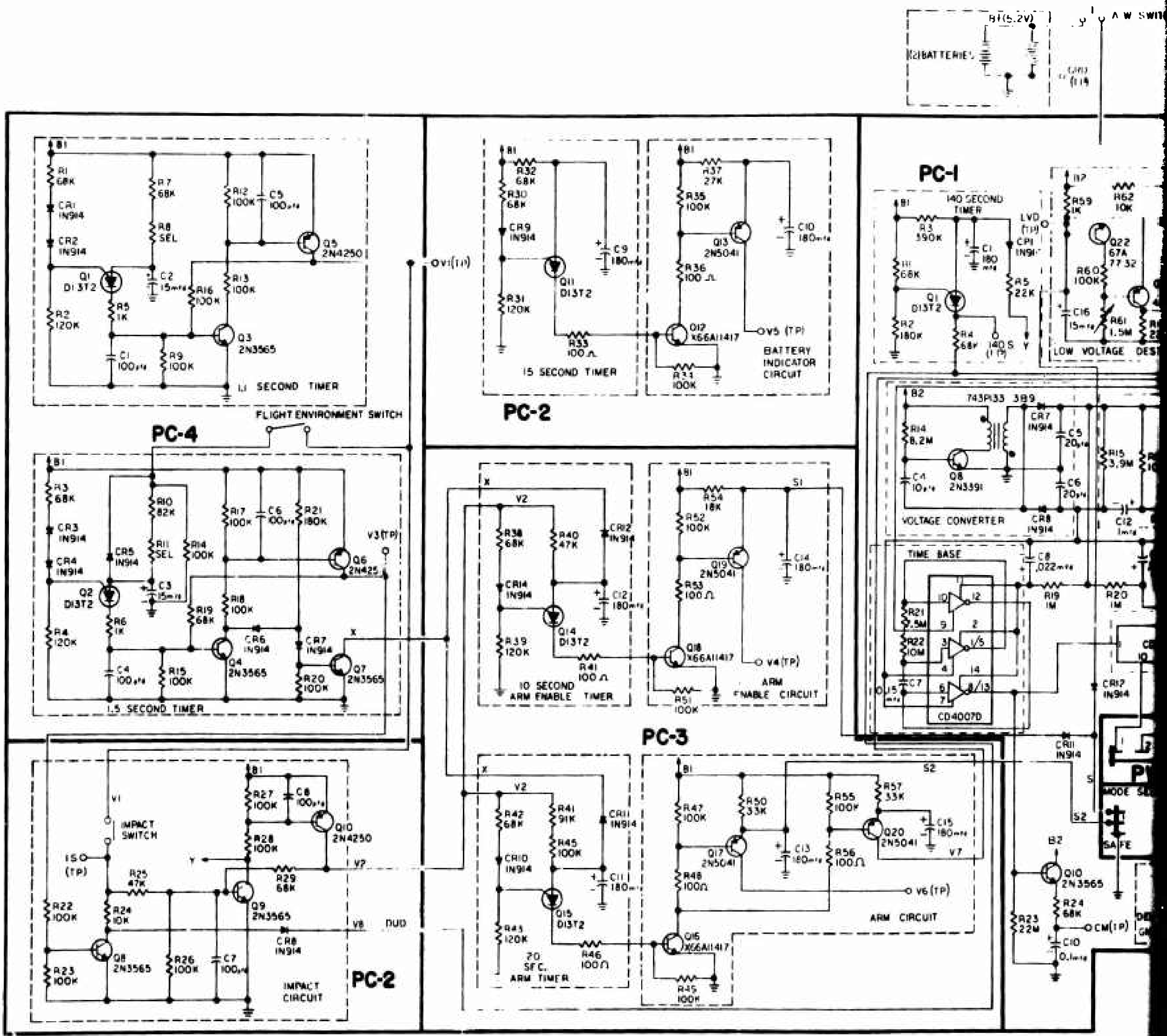
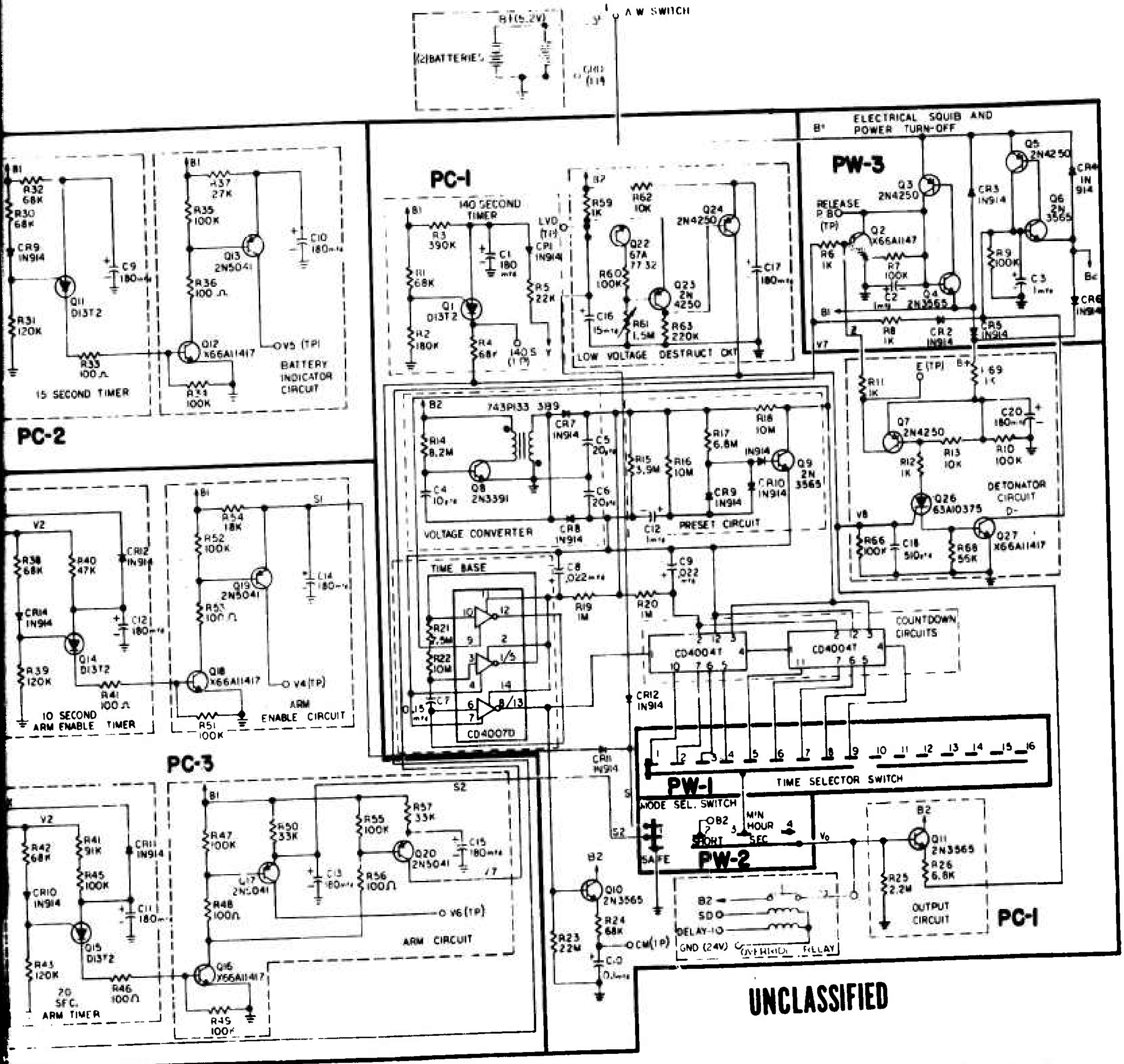


Figure 7. Schen

2 TP TEST POINT USED TO MONITOR FUZE FUNCTION.
1-ALL RESISTORS ARE 1/8W CARBON COMPOSITION

(The re

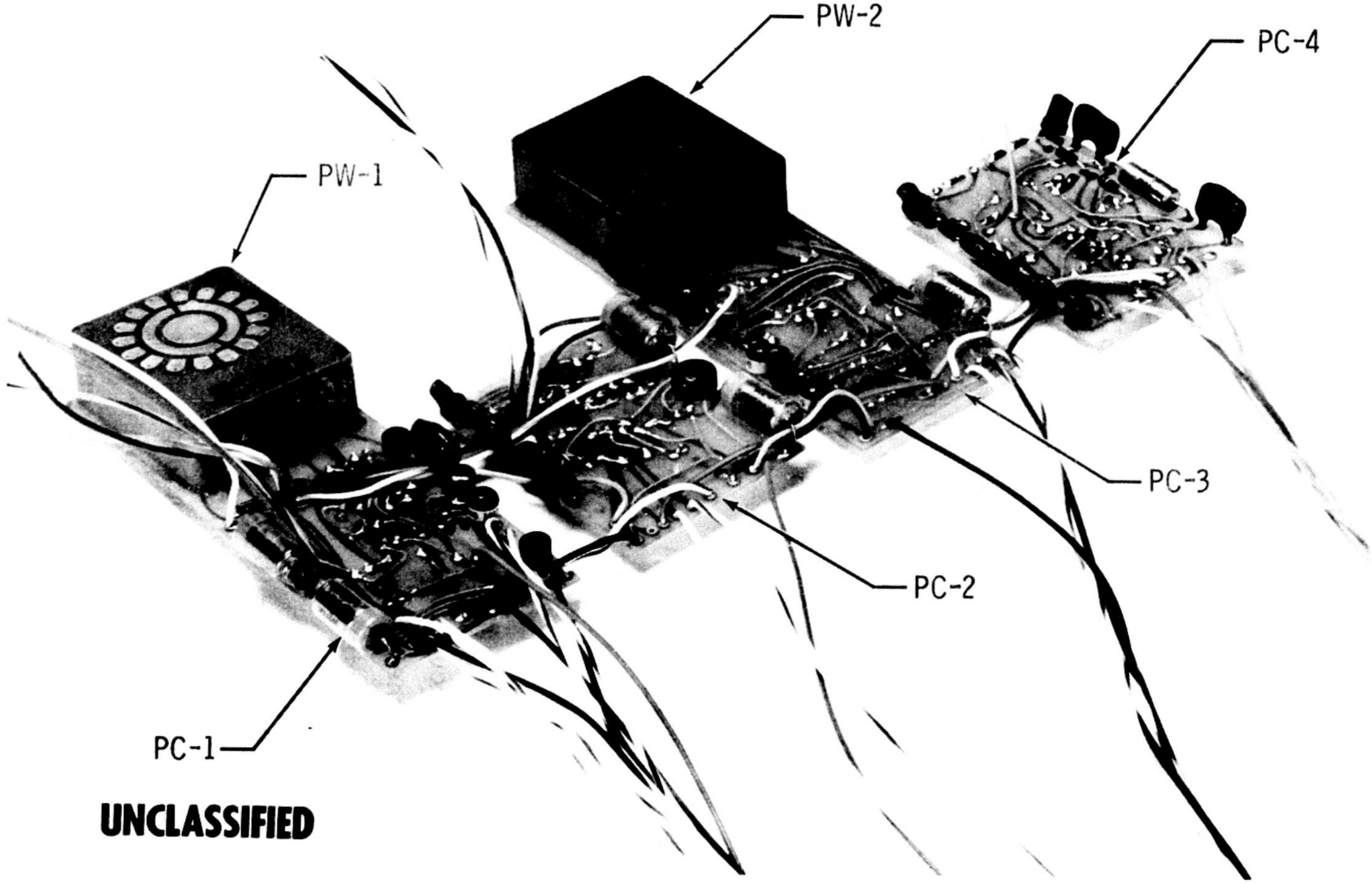


UNCLASSIFIED

Figure 7. Schematic of VLDF (Ground-Settable)

(The reverse of this page is blank)

NOTE: THE DESIGNATIONS SHOWN REFER TO CORRESPONDING REFERENCES ON THE SCHEMATIC (FIGURE 7).



UNCLASSIFIED

Figure 8. Packaging Concept, Electronic Circuits for Ground-Settable Fuze

(U) The 1.1-second timer (see Figure 7) is an application of a PUT in a timing circuit. In this circuit, the anode of the PUT (Q1) is connected to the junction of R8 and C2. The anode gate is connected to the junction of R2 and CR2. The output terminal (the cathode) is connected to R5. When B1 power is applied to the circuit, R1 and R2 establishes the anode gate voltage reference level. The anode potential, initially held at ground, will rise slowly as C2 is charged by the current provided and controlled by R7 and R8. The PUT is triggered on when the anode voltage exceeds the anode gate reference level by approximately 0.5 volt, at which time a positive voltage pulse is applied to the cathode terminal. The desired firing time of the PUT is a function of the anode gate reference level and the charging rate of C2. Diodes CR1 and CR2 provide temperature compensation. The accuracy of the PUT timers in the VLDF is ± 10 percent, unless specified otherwise.

(U) The design characteristics of the electronic circuits included in the ground-settable fuze are discussed in the following paragraphs.

a. 1.1-Second Timer - (U) The 1.1-second timer is initiated as soon as B1 power is available (when the battery is initiated). After 1.1 seconds of operation, Q1 provides an output which turns on the latching circuit of Q3 and Q5. A feedback network through R16 ensures that Q3 and Q5 continue to conduct for as along as B1 power is maintained. Capacitors C1 and C5 prevent the latching circuit from triggering due to noise. The output of the latching circuit of the 1.1-second timer (marked V1 in Figure 7) provides a gating signal to the impact switch.

b. 1.5-Second Timer - (U) The 1.5-second timer (in the deliverable models) is initiated by the application of B1 power. In an operational fuze, the flight environment switch would provide B1 power to CR5, R10, and R14. Thus, in an operational fuze, the final output of the 1.5-second timer is dependent upon closure of the flight environment sensor (FES) switch for a period of at least 1.5 seconds, at which time the PUT would trigger the latching circuit of Q4 and Q6. Since an FES switch was not included in the deliverable models, the 1.5-second timer was designed automatically to

(U) Continued
time out 1.5 seconds after the application of B1 power. The latching circuit operates in the same manner as the latching circuits of the 1.1-second timer. The output of the 1.5-second timer (V3) disables the dud function in the impact circuit.

(U) Transistor Q7 provides an additional safety feature in the 1.5-second timer. When B1 power is first applied to the circuit Q7 conducts, thus grounding output X and disabling the 10-second arm enable timer and the 20-second arm timer. Once Q4 turns on, Q7 is turned off, and the arm timers are enabled.

c. Impact Circuits - (U) The impact circuit provides three functions: memorization of the momentary closure of the impact switch, a source of power for the arm timers, and the generation of a dud signal in the absence of a proper flight environment. The impact switch is enabled by the output of the 1.1-second timer. At impact, a typical latching circuit (Q9 and Q10) is triggered. The output of the latch (V2) provides operating power to the 10-second arm enable timer and 20-second arm timer. If the output of the 1.5-second timer (V3) is not available when the impact switch closes (thus Q8 does not conduct), line V8 goes positive and a dud signal is applied to the detonator circuit. The presence of output V3 prevents the dud function by saturating Q8, and thus grounding the V8 line.

d. 15-Second Timer/Circuit - (U) The 15-second timer is initiated by the application of B1 power. Timing is accomplished by a standard PUT circuit which drives the battery indicator circuit. The energy necessary to fire the battery indicator dimple motor is stored in C10. The output of the PUT timer drives a two-stage amplifier circuit (Q12 and Q13), thus discharging C10 through the bridgewire of the dimple motor.

e. 10-Second Arm Enable Timer/Circuit - (U) The 10-second arm enable timer and its associated arm enable circuit function in the same manner as the battery indicator circuit. The 10-second arm enable timer is initiated

(U) Continued
at impact, when V2 is generated. To initiate, the 10-second arm enable timer must also be enabled by the output of the 1.5-second timer. The energy necessary to fire the arm enable dimple motor is stored in C14. If the mode select switch is in the SAFE position, C14 is grounded and the arm enable function is prevented.

f. 20-Second Arm Timer/Circuit - (U) The 20-second arm timer and its associated arm circuit are similar in function to the arm enable circuits, except that the timer is calibrated to provide an output 20 seconds after impact. An additional output circuit (Q20 and C15) provides a signal which fires the power control squib switch. When the fuze is in the SAFE position, the capacitor that fires the arm circuit piston actuator (C13) is shorted to ground; however, as discussed previously, the power control squib switch is fired by the output of C15, which is permitted to charge in order to provide the dud function required in the safe mode.

g. 140-Second Timer - (U) The 140-second timer is initiated by the application of B1 power. During the timing period, a low voltage (0.1 volt or less) is maintained across the E-Cell (E4), thus holding Q21 off. If the E-Cell is permitted to time out, the voltage potential across the E-Cell increases until Q21 turns on and produces a dud signal. In a proper operating sequence, the 140-second timer is turned off before it times out (since B1 power which operates the timer is turned off 20 seconds after impact).

h. Short-Delay Event Timer - (U) The short-delay (100 milliseconds to 1 second) timing function is implemented by the E-Cell output circuit consisting of Q28, C19, and the thick film resistor network. When the mode selector switch is set to either the SAFE or SHORT position, no positive reference is provided to the time selector switch; therefore, C19 begins charging through a portion of the thick film resistor network as soon as B2 power is available. When the voltage across C19 exceeds the turn-on voltage of Q28, Q28 produces an event or dud signal.

i. Long-Delay Timer - (U) The long-delay timing function is implemented by three E-Cells: E1, E2, and E3, one of which, as selected, discharges through an appropriate portion of the thick film resistor network. Event times between 1 hour and 10 hours are provided by E1, a 40 microampere/hour E-Cell. To achieve a specific delay within this range, the mode select switch is set to HOURS, and a specific time is selected with the time selector switch. The operation of the timing circuit is identical to that of the 140-second timer.

(C) Event times ranging from 1/2 day to 5 days are provided by the 480 microampere/hour E-Cell (E2). To achieve a delay in increments of days, the mode select switch must be set to DAY. Event times ranging from 6 days to 30 days are provided by E2 (2650 microampere/hour capacity). The complete range of time delays available with the deliverable models of the ground-settable fuze is listed in Table I.

j. Back-Up Timer - (C) The back-up timing function is accomplished by discharging the 2650 microampere/hour E-Cell (E5) through R64, the action of which produces an output from Q25 at the end of the delay period. The time delay thus obtained is approximately 30 days.

k. Low-Voltage Destruct Circuit - (U) The low-voltage destruct (LVD) circuit is calibrated to trigger the detonator circuit if B2 power should decrease below 2.6 volts or if B2 power should be terminated. Under normal conditions, Q23 conducts and thus holds Q24 off. Under these conditions, the base-to-collector junction of Q22 conducts in a normal forward direction. Resistors R60 and R61 establish the base voltage level and, therefore, the cut-off level of Q23. Capacitors C16 and C17 stabilize the circuit and thus prevent an LVD function due to a transient signal caused by bouncing of the squib switch contact when the power control circuit is first activated (or at any other time). When B2 power decreases to a level which will permit the LVD circuit to be triggered, the base-to-collector junction voltage of Q22 decreases, due to a decrease in conducting current, below the breakover voltage. This action results in a slight increase in

TABLE I. EVENT DELAYS AVAILABLE WITH GROUND-SETTABLE FUZE

POSITION OF TIME SELECTOR SWITCH	DELAY			EFFECTIVE RESISTANCE OF THICK FILM RESISTOR NETWORK (K OHMS)
	HOURS, AS PROVIDED BY E1	DAYS, AS PROVIDED BY E2	DAYS, AS PROVIDED BY E3	
1	1.0	0.5		106
2	1.5	0.75		154
3	2.0	1.0		204
4	3.0	1.5		304
5	4.0	2.0		404
6	5.0	2.5		504
7	6.0	3.0		592
8	8.0	4.0		772
9	10.0	5.0		972
10			6	204
11			9	304
12			12	404
13			15	504
14			18	592
15			24	772
16			30	972

CONFIDENTIAL

(U) Continued

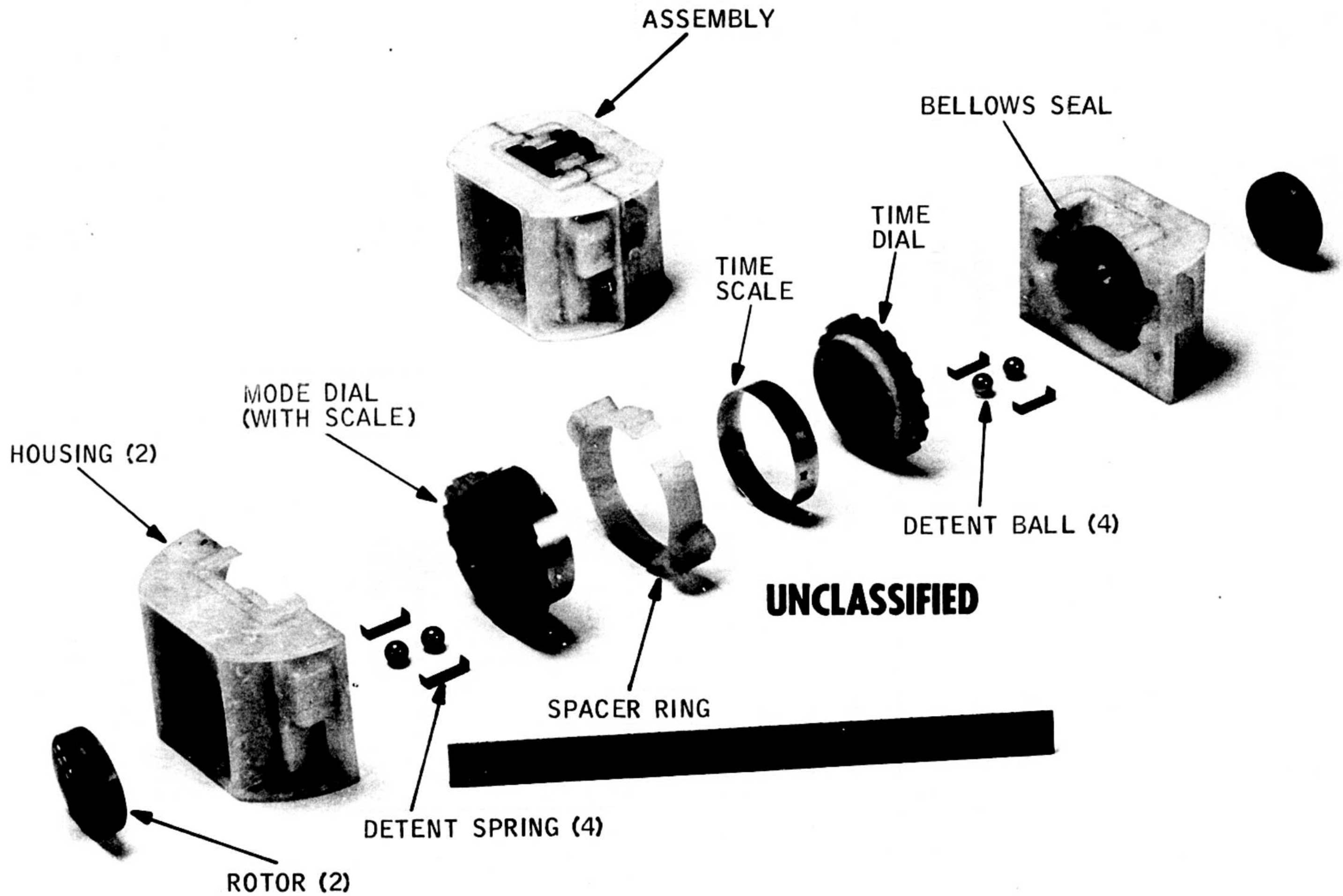
Q23 base voltage, which results in a partial turn-off of Q23. As a result, Q24 turns on, permitting C17 to discharge through the anode gate of Q26 in the detonator circuit.

l. Detonator Circuit - (U) The detonator circuit is a high gain amplifier. In an operational fuze, its sole function is to electrically initiate the detonator.

(U) In the deliverable models, a piston actuator replaced the detonator. The piston actuator provides an indication of event and dud functions. The detonator circuit receives power directly from the ammonia battery. The energy required to fire the piston actuator is stored in C20. The time constant to initially charge C20 was selected to permit firing the detonator circuit any time after 1.1 seconds from fuze initiation (which is the earliest time at which a dud function can occur). The circuit is triggered by a positive pulse applied to the gate of Q26. The resultant output of Q26 drives the base of Q27; thus Q27 turns on and thereby provides a discharge path for C20 through the piston actuator. The SCR (Q26) provides a self-latching feature, as well as a capability for high gain.

3. Setter

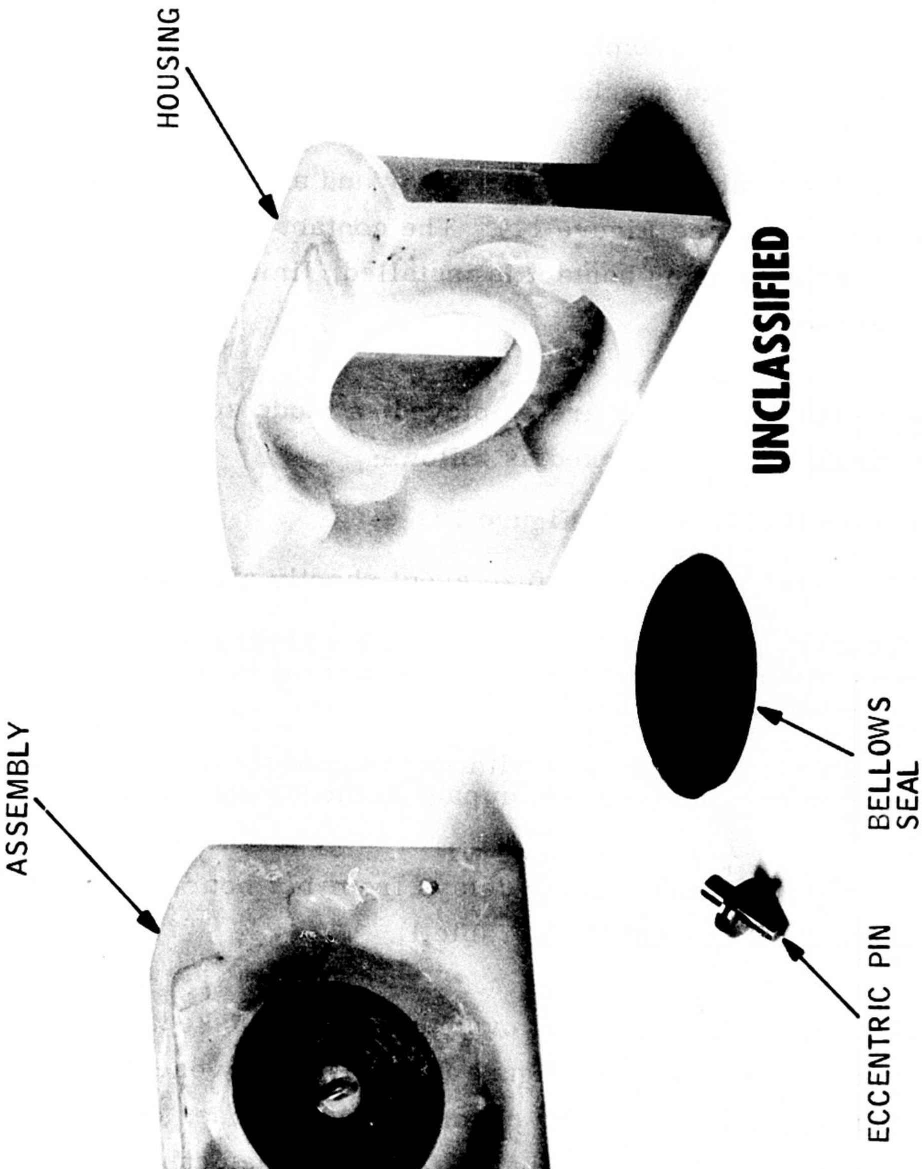
a. Assembly - (U) The functional components of the setter, shown in Figure 9, consist of two 16-position switches and two rotor/contact assemblies. The axes of the switches are perpendicular to the center axis of the fuze. As shown in Figure 9, all of the functional components except the rotor are contained within two identical housings, which are bonded together in the setter final assembly. The detent balls are held captive between the setter housings and the spacer ring and react against molded indentations in the mode and time dials. The mode and time scales are mounted to the appropriate dials (the mode scale is shown in application in Figure 9). Environmental seals are provided by the bellows seals. Each seal, together with an associated eccentric pin which is bonded to the seal, is bonded to a setter housing (see Figure 10). The two rotors,



UNCLASSIFIED

[redacted]

Figure 9. Setter



UNCLASSIFIED

Figure 10. Setter Housing

(U) Continued
which are physically connected to the associated dials by the eccentric pins, contain contacts which provide electrical connections between various components of the electronic circuit boards located in the setter housings. Thus, the rotor/contact assemblies interconnect specific electronic circuits corresponding to discrete angular positions of the mode and time dials.

(U) The rotor assembly consists of a rotor and a spring contact which is bonded to the rotor (see Figure 11). The contact block, which is bonded to the rotor after the spring contact is installed, limits the radial movement of the contact.

b. Scales - (U) Two scales are employed, a mode scale and a time scale. The mode scale is marked as follows:

. SAFE (see illustration in Figure 12)

. SHORT, which provides for fuze event shortly after arming

. HRS (hours), which, in combination with a setting of the time dial, provides various discrete delays from arming in increments of one hour (see example in Figure 13)

. DAY, which, in combination with a setting of the time dial, provides various discrete delays from impact in increments of one day.

(C) The time scale is marked for delays from 1/2 hour to 30 days (see complete list of available delays in Table I).

(U) The scales are appropriately overlapped and masked. As installed in the setter, the spacer ring (see Figure 9) exposes only one discrete position of the setter at any one time. For example, in one case, only the word "SAFE" would be exposed (as in Figure 12); in another case, exposure of the HRS scale would be combined with the exposure of a discrete selected number from the time scale, as in the case in Figure 13 where the number "1" is exposed.

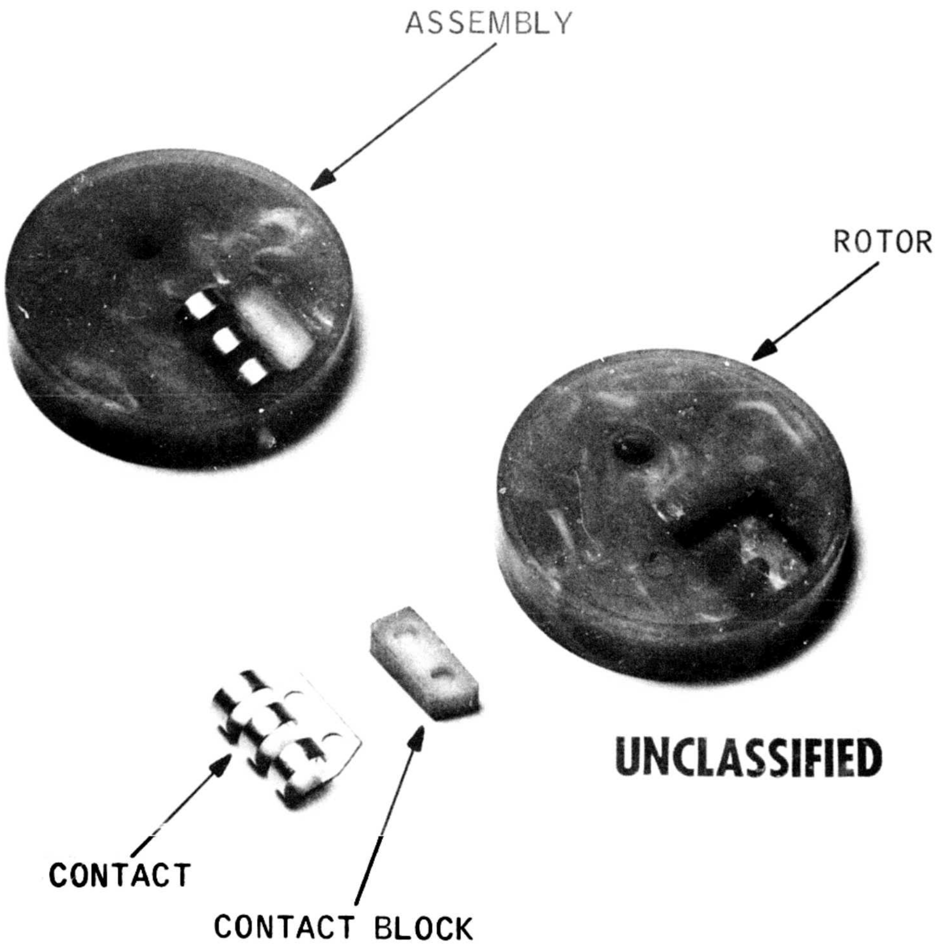
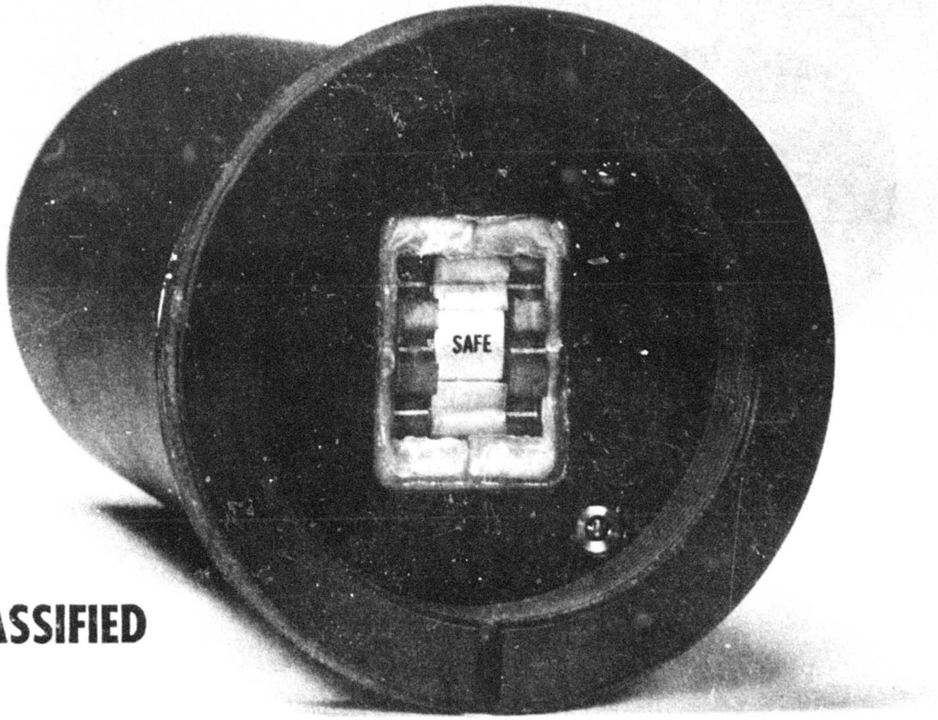
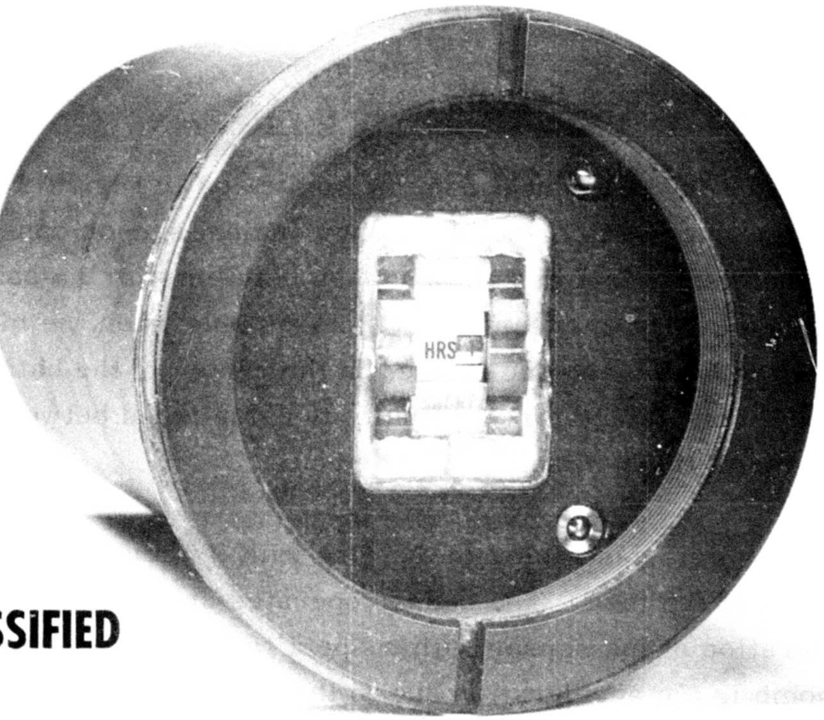


Figure 11. Rotor



UNCLASSIFIED

Figure 12. Fuze Set to Safe Mode



UNCLASSIFIED

Figure 13. Fuze Set to 1-Hour Delay Mode

c. Materials - (U) Wherever possible, the materials specified for setter components were selected for adaptability to mass production techniques. The setter housing, rotor, dials, and spacer ring are fabricated of glass-filled nylon which is compatible with high-speed injection molding techniques. The designs for the setter scales, detent spring, eccentric pin, and bellows seal are compatible with conventional high-production techniques.

4. Flight Environment Sensor

(U) The flight environment sensor is illustrated in Figure 14. Essentially an inertial mercury switch, the flight environment sensor consists of two concentric hemispherical contact surfaces between which a ball of mercury is free to travel. The mercury switch closes only when the mercury ball is in contact with an electrode located in the center of the baffle and terminal subassembly; thus, electrical continuity is established between the terminal and either one of the hemispherical contacts.

(U) The sensor is assembled in the fuze with its central axis parallel to the main axis of the fuze. The sensor operates on the principle that the only acceleration of the sensor with respect to a free-falling "weather-cocked" bomb is the acceleration due to the aerodynamic drag along the flight path of the bomb. This means that aerodynamic forces are minimal (near zero g) in a plane normal to the longitudinal axis of the munition, and that the only appreciable force present is the force due to drag along the longitudinal axis. When this condition exists, the mercury ball is forced against the terminal assembly, and the flight sensor circuit is closed.

(U) When the munition experiences any condition other than free flight, the differential gravitational force active between the mercury ball and the munition is 1 g. Thus, with the munition in a horizontal attitude, the mercury ball will not make contact with the terminal assembly. The design of the hemispherical surfaces is such that when the munition is in a horizontal attitude, a force greater than 3 g's along the longitudinal axis is required to close the flight sensor.

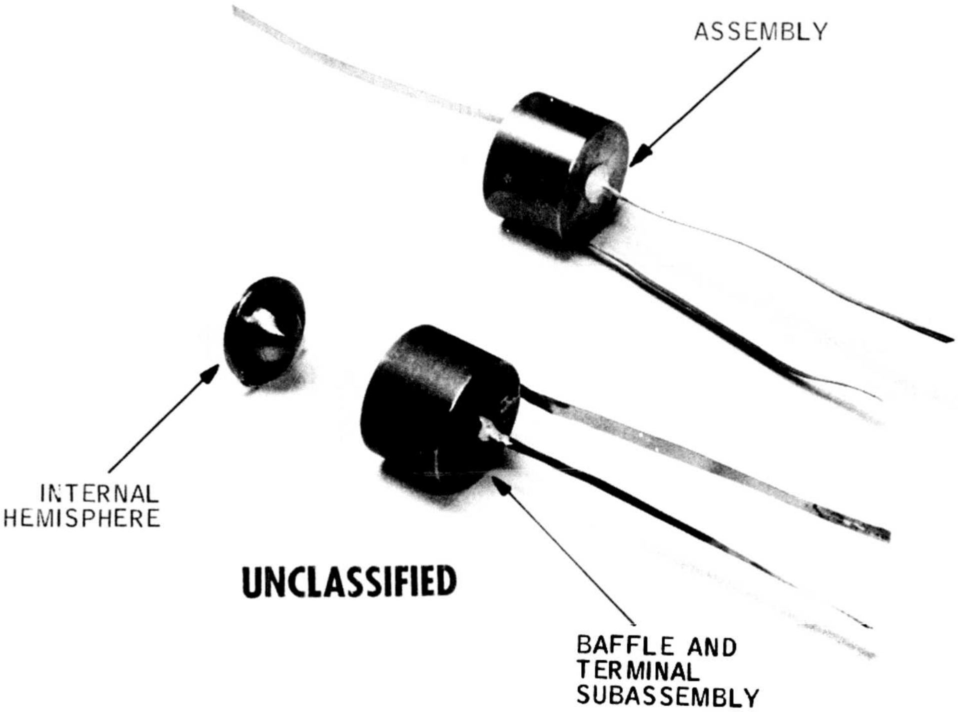


Figure 14. Flight Environment Sensor

(U) The flight environment sensor circuit closes only when the mercury ball is within 18 degrees of the longitudinal axis of the sensor. A baffle is used to prevent rapid oscillations of the mercury ball. The mercury is alloyed with thallium to permit operation down to -65°F. The sensor is sealed with an inert atmosphere to prevent oxidation; thus a low contact resistance is maintained between the electrodes and mercury.

(U) The flight environment sensor is capable of detecting a drag force as low as 0.1 g (which corresponds to the g force experienced by a clean munition released at 300 knots). Since the sensor is sensitive in only one direction, two sensors would be required in a fuze adaptable to both nose and tail well installations.

5. Safing and Arming Mechanism

(U) The component parts of the safing and arming (S&A) mechanism are illustrated in Figure 15. The S&A mechanism includes three subassemblies: the arm enable unit, the arming unit, and the flight environment sensor.

(U) The arm enable mechanism is designed to ungag the arming slide on command from the fuze electronics. A signal from the fuze electronics fires the arm enable dimple motor, the output of which reacts against the slide release pin which, in turn, depresses the slide lock pin which is spring-loaded within the arming slide. Once depressed, the surface of the slide lock pin is aligned with the guide surface of the housing, thus enabling the arming slide to be driven into the "arm" position.

(U) The arming slide, which contains the explosive lead, acts as the interrupting shutter in the explosive train. In the unarmed position, the arming slide acts as a barrier between the detonator and booster. After the arm function is enabled, the arming slide is driven into the armed position by the arming piston actuator. The slide retainer holds the piston actuator (which replaced the detonator in the deliverable models) and also holds the arming slide in position.

NOTE: IN DELIVERABLE MODELS, PISTON ACTUATOR REPLACED DETONATOR. PISTON ACTUATOR FUNCTIONS AS EVENT INDICATOR.

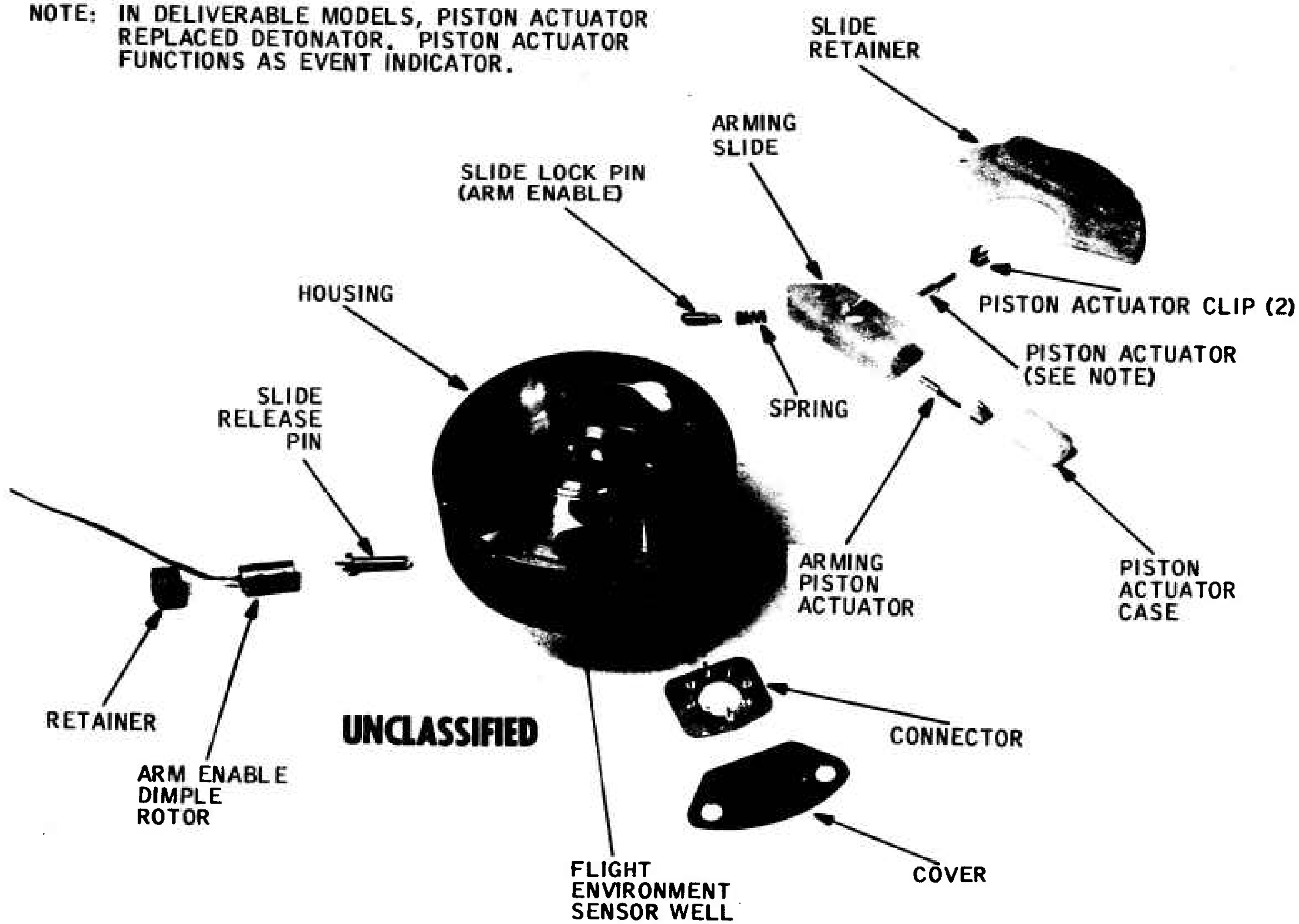


Figure 15. Safing and Arming Mechanism

(U) In the fully operational fuze, the flight environment sensor would be part of the S&A mechanism. The flight environment sensors delivered during Phase II were supplied separate from the fuzes to facilitate independent testing and evaluation.

(U) The connector in the housing of the S&A mechanism provides a means of electrical connections between the control electronics and the explosive components in the S&A mechanism. This connector also provides a means of electronically monitoring the fuze event.

6. Impact Switch

(U) The impact switch, shown in Figure 16, is a momentary contact type consisting of a support spring, a contact mass, a contact shell, and an insulating damper. The support spring positions the contact mass against the insulating damper with a force sufficient to prevent free vibration of the mass. On impact, the inertia of the mass forces the mass into momentary contact with the contact shell.

(U) The closure range of the impact switch is from 40 to 80 g. The impact switch is sensitive in only three directions; it is "blind" in the direction toward the insulating damper. Because the impact switch is sensitive in only three directions, two impact switches, mounted back to back, are used for both nose and tail well application.

7. Explosive Train

(U) The explosive train developed for the Very Long Delay Fuze is shown in Figure 17. The explosive train consists of a Honeywell miniature electric detonator, a lead, and a booster. For the models delivered during Phase II, the booster was inert, the lead was not included, and the detonator was replaced by a piston actuator which served as an event indicator. The specific designs defined for each component are discussed in the following paragraphs.

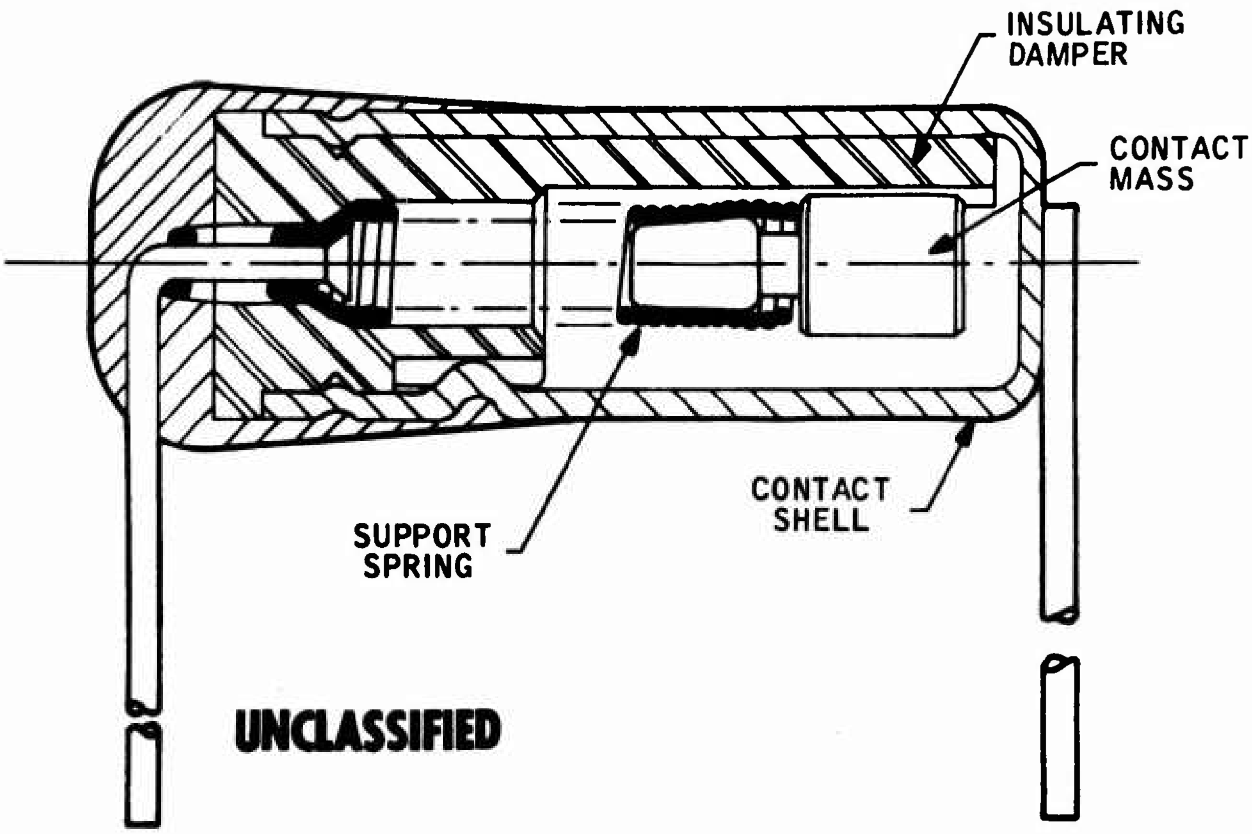


Figure 16. Impact Switch

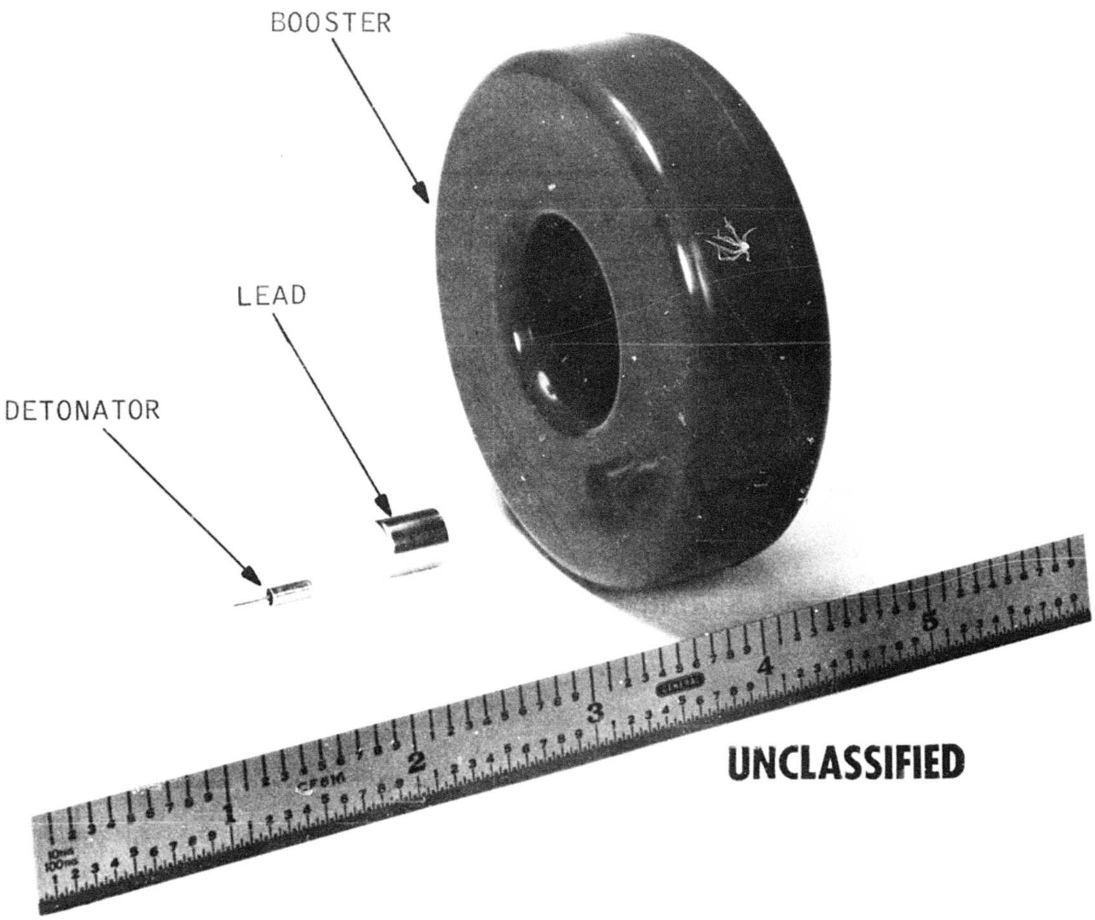


Figure 17. Explosive Train

a. Detonator - (U) The Honeywell miniature electric detonator specified for the VLDF has a diameter of 0.100 inch and a length of 0.35 inch, including the contact pin. The output charge is 13 mg of HMX. The output is focused by the detonator tip, which is fabricated in a Miznay-Schardin configuration. The demonstrated capability of this detonator for initiating secondary explosives over relatively large air gaps makes it highly adaptable to the VLDF application.

b. Lead - (U) The explosive component of the lead is PBXN-5, as approved for used by MIL-STD-1316. The PBXN-5 is cold pressed into an aluminum cup (per QQ-A-250/1) at 15,000 psi, providing a density which is 89 percent of the theoretical maximum density. The particle size of the PBXN-5 used in the leads fabricated for testing during Phase II ranged from 800 to 400 microns. The lead is sealed by an aluminum cover (per MIL-A-148).

(U) The lead is cylindrical with a diameter of 0.3 inch and a length of 0.3 inch. The lead is out of line when in the "SAFE" position.

c. Booster - (U) The booster is sized for 150 grams of CH-6, as approved for use by MIL-STD-1316. The CH-6 is pressed to a density of approximately 90 percent of the theoretical maximum density.

8. Battery Power Supply

(U) The ammonia battery power supply used in the VLDF is shown in Figure 18. The ammonia battery is non-aqueous, and will therefore operate reliably over the operational temperature range specified. Evaluation tests conducted to date indicate a shelf-life capability of greater than 10 years without loss in capacity, an active-life capability of several months, voltage and current characteristics compatible with the VLDF application. In addition, tests indicate that the ammonia battery can withstand the temperature, shock, vibration, and impact shock to which the Very Long Delay Fuze will be exposed.

UNCLASSIFIED

Figure 18. Arming Battery Power Supply

(U) Isolation of the power supply in the Very Long Delay Fuze is accomplished by the complete separation of the ammonia battery activating agent from the Electro-Chemical cell, within the battery, until fuze initiation.

(U) The ammonia battery does not need recharging or replacement and is hermetically sealed. This prevents any battery liquids or gases from escaping, with possible damage to adjacent components, and permits complete encapsulation of the battery within the fuze. This enables the fuze container solidly to support all components for the greatest shock resistance.

(U) In Figure 18, the ammonia battery is shown mounted to the support plate. The percussion primer is located in the counterbore in the top of the battery. When the battery firing device strikes the percussion primer, the battery is initiated.

9. Battery Firing Device

(U) The battery firing device is shown in Figure 19. In the design application, the lanyard is attached to the exposed end of the lanyard rod. When the munition is released, the force exerted by the lanyard pulls the lanyard rod and the firing pin (which are connected by the firing pin clips) back against the firing pin spring. When the firing pin reaches the end of its backward stroke, the clips are pulled back beyond the end of the barrel and released outward. With the firing pin clips released, the firing pin is driven forward into the battery percussion element by the firing pin spring, and the battery is initiated.

(U) The battery firing device is threaded into the housing of the S&A mechanism. An O-ring provides an environmental seal. The barrel, which holds the firing pin clips against the firing pin until release, slides within the housing and is spring loaded by the return spring. Four return spring pins

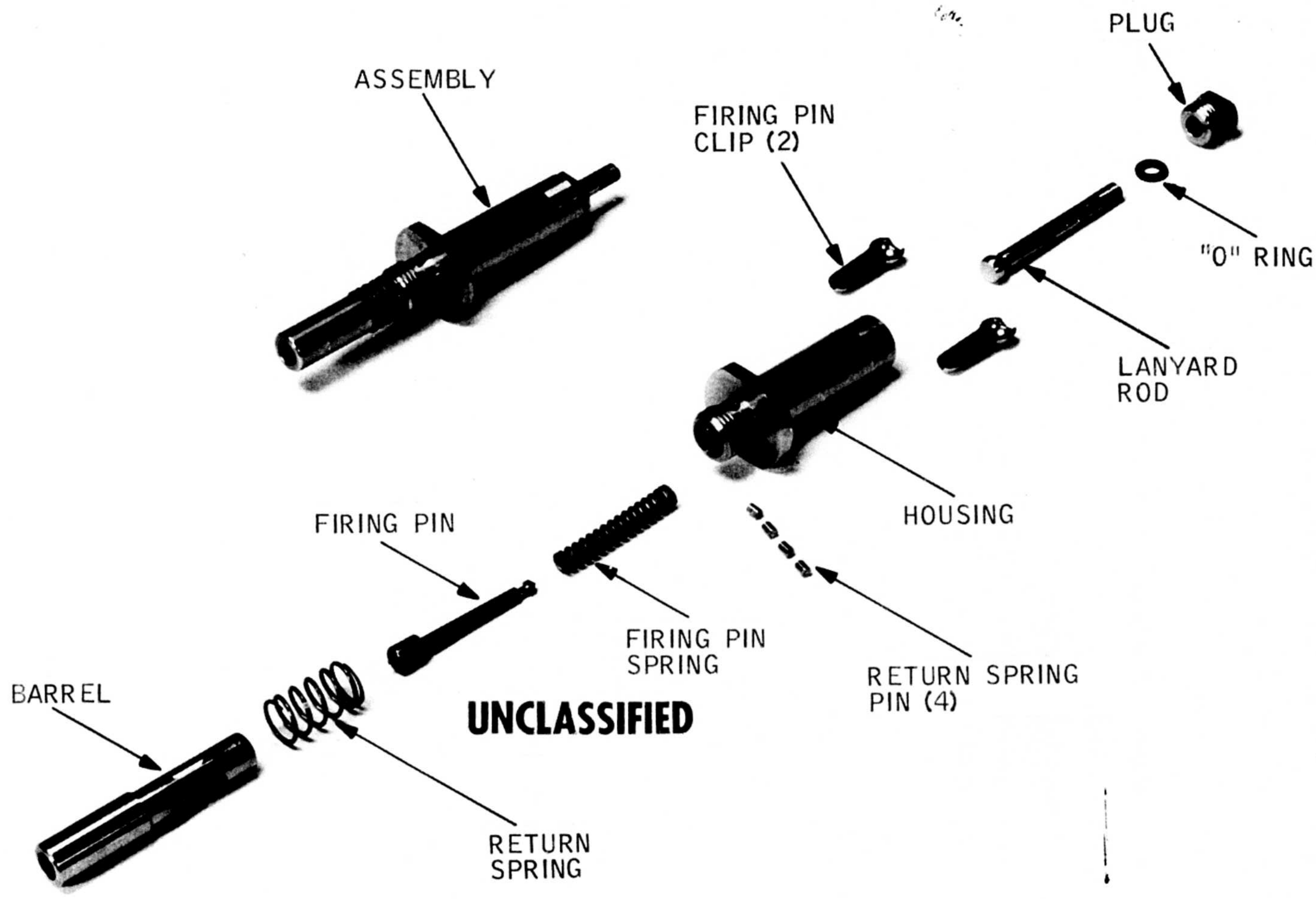


Figure 19. Battery Firing Device

(U) Continued
hold the barrel against the return spring. The return spring allows the barrel to slide backward into the housing of the battery firing device, and thus prevents inadvertent firing of the battery due to the impact shock of a jettison safe release.

(U) The pull force which must be exerted by the lanyard to activate the battery is in the range from 20 to 22 pounds. The total force consists of the force required to compress the firing pin spring.

(U) The force required to operate the battery firing device can be increased by including a shear wire between the lanyard rod and the housing. The shear wire can be sized for various pull-force requirements. Tests conducted with a number 22 AWG copper wire indicated a force requirement of 40 ± 5 pounds. The shear wire is intended for use as an additional safety device during fuze assembly, and was not included in the deliverable models.

10. Battery Status Indicator

(U) The battery status indicator, shown in Figure 20, provides an indication (discernible by both sight and touch) that the battery has been initiated. The indicator, which is mounted so the unactivated indicator is flush with the fuze face, consists of a dimple motor, an indicator rod, a shear pin, and a housing.

(U) The battery status indicator operates as follows. The output of an initiated battery fires the dimple motor. The force of the dimple motor output shears the shear pin and drives the indicator rod into a position in which the indicator rod protrudes from the face of the fuze.

11. Anti-Withdrawal Switch

(U) The anti-withdrawal switch is shown in Figure 21. The anti-withdrawal switch assembly is designed to event the fuze if an attempt is made

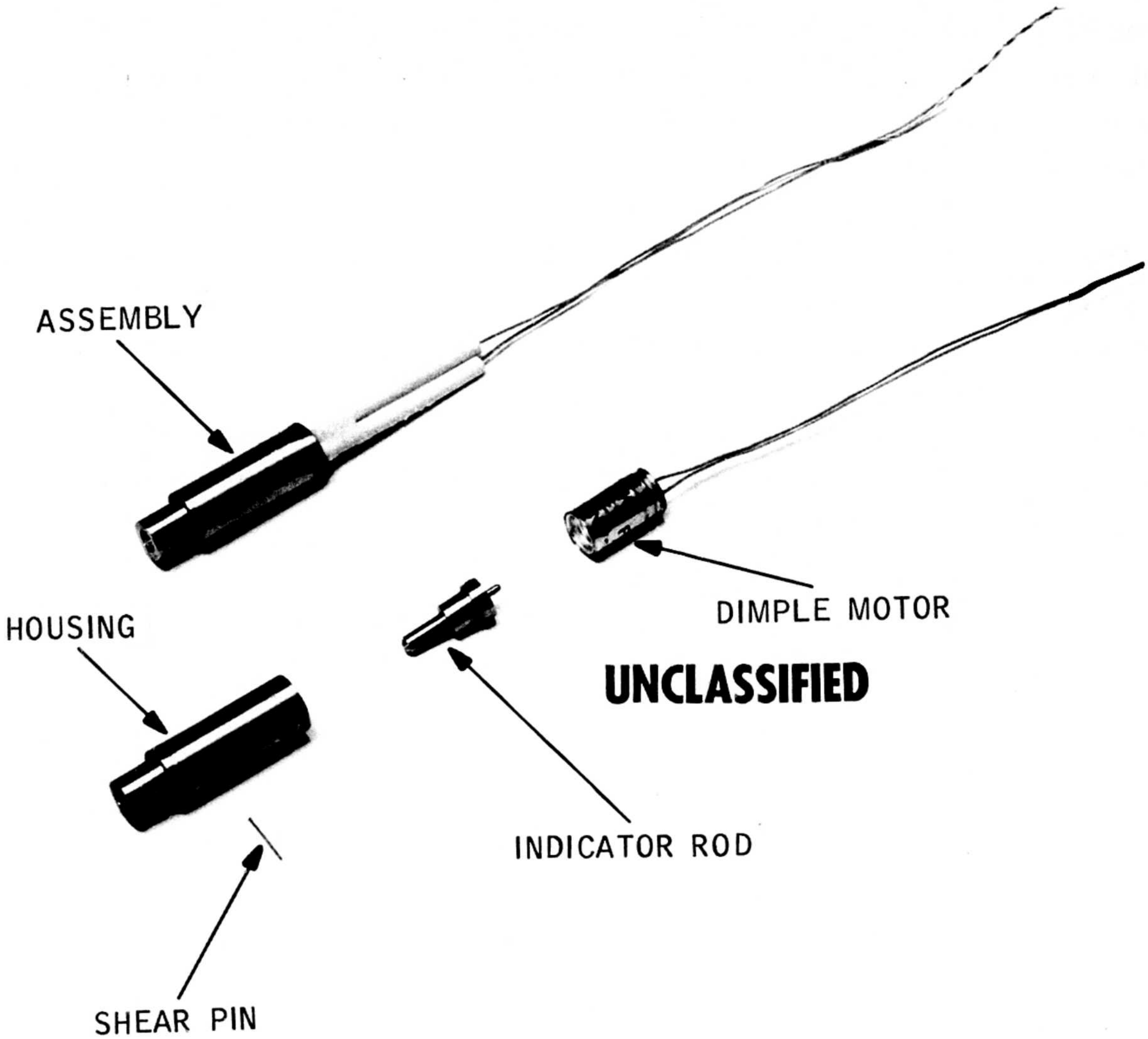


Figure 20. Battery Status Indicator

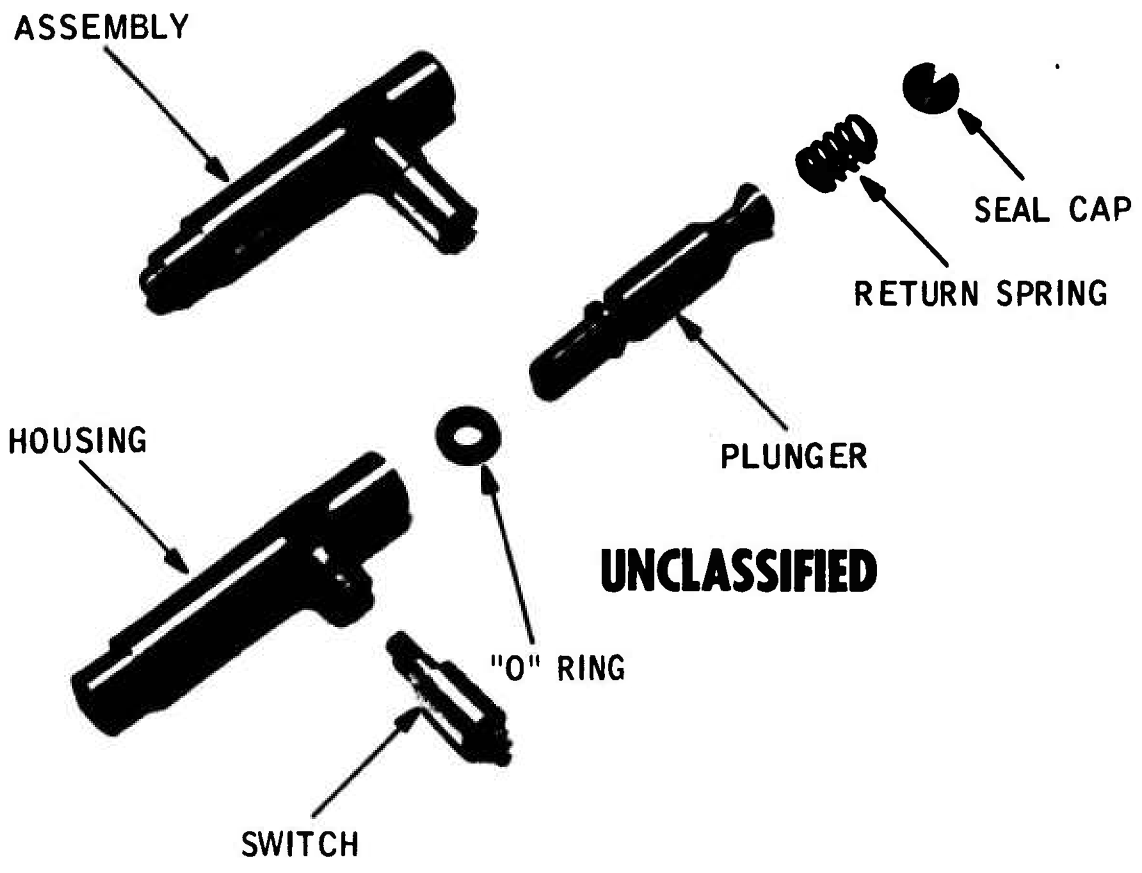


Figure 21. Anti-Withdrawal Switch

(U) Continued

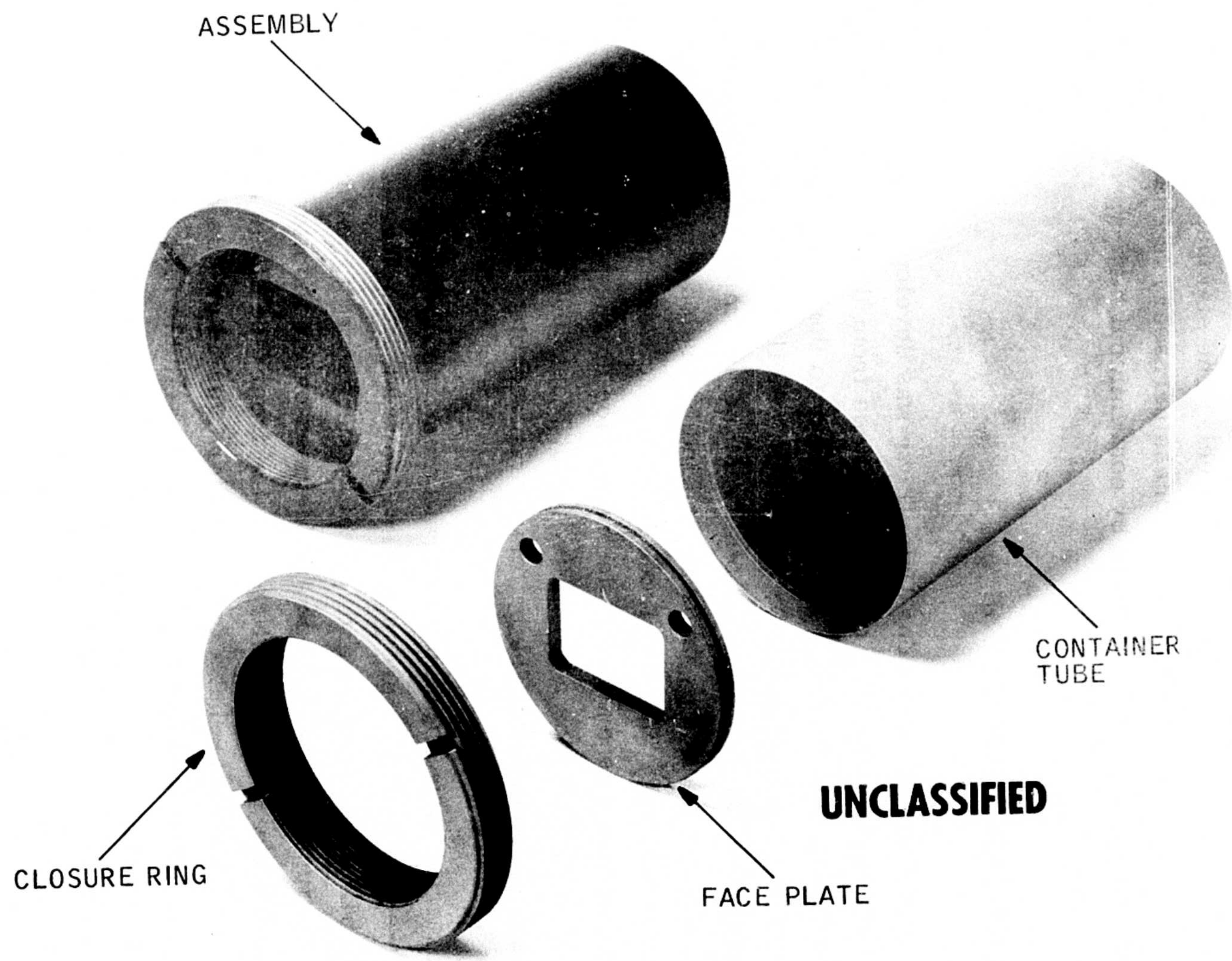
to remove the fuze well closure after the fuze has armed. The anti-withdrawal switch consists essentially of a plunger with an integral cam and a single-pole single-throw, normally open switch. The plunger moves inward as it reacts with the fuze well closure; at the same time, the integral cam operates the switch. A return spring holds the plunger against the fuze well closure. An O-ring provides an environmental seal. The design is such that shock impact forces are decoupled from the switch.

(U) The anti-withdrawal switch design developed during Phase II can be modified to also include a capability for switching fuze power. This additional capability would be implemented by modifying the normally open switch to a normally closed switch, and by making minor changes to connections in the electronics circuitry. Also, the plunger would be fitted with a safing pin. With this modification to the anti-withdrawal switch, power would be applied to the fuze only after the safing pin was removed and the plunger was depressed by the fuze well closure.

(U) The anti-withdrawal switches in the fuzes delivered during Phase II were disconnected from the fuze electronics to enable the fuzes to be recovered intact. The function of the anti-withdrawal switch can be monitored at test points external to the fuze.

12. Container

(U) The fuze container is shown in Figure 22. The container consists of a container tube, a face plate, and a closure ring. In assembling the container assembly, the face plate is first welded into a recess in the container tube. Then the closure ring is welded into the same recess. Welding the closure ring to the container tube provides maximum strength against impact shock. When the fuze is used in a nose well application, the welded joints prevent "slack" in the closure ring, and thus eliminate a possible cause of fuze failure upon impact. When used in a tail application, the welded closure ring imparts maximum support.



UNCLASSIFIED

Figure 22, Container

(U) The container tube can be fabricated from readily available material by high-production methods. The face plate is designed for fabrication by high-speed stamping from high-strength steel. The stamped components would be heat treated to provide the hardness necessary to ensure survival. The closure ring can be manufactured by conventional high-speed production techniques.

B. COCKPIT-SETTABLE FUZE

(U) One model of the Very Long Delay Fuze was developed to demonstrate the feasibility of selecting fuze control functions from the cockpit by the pilot. The model, which is functionally similar to the ground-settable fuze, was designed for use in a demonstration unit to facilitate its evaluation. Accordingly, functions which would otherwise be accomplished automatically in the fuze were simulated by controls and indicators on a monitor panel on the demonstration unit, and the circuits in the fuze were appropriately modified to achieve this end. The demonstration unit is powered by a 5.2-volt battery which provides a capability for at least 2000 demonstrations of the various fuze functions. The battery is replaceable.

(U) An exterior view of the demonstration unit which was developed for the cockpit-settable fuze is presented in Figure 23. The fuze is self-contained, and all of the controls and indicators necessary for simulating and observing the functions of the fuze are included on the monitor panel. The desired event delay is set by switches on the front face of the fuze (as with the ground-settable fuze), but a capability for overriding this delay with a short-event function is provided in the cockpit-settable fuze by the MODE FUNCTION switch. This feature simulates a corresponding function of the USN Fuze Function Control Set AN/AWW-4 with which the cockpit-settable fuze is ultimately intended to function.

(U) In a typical demonstration of the cockpit-settable fuze, the release cable and monitor cable would be connected to the monitor panel and fuze, respectively, as indicated in Figure 23. After the event delay is selected

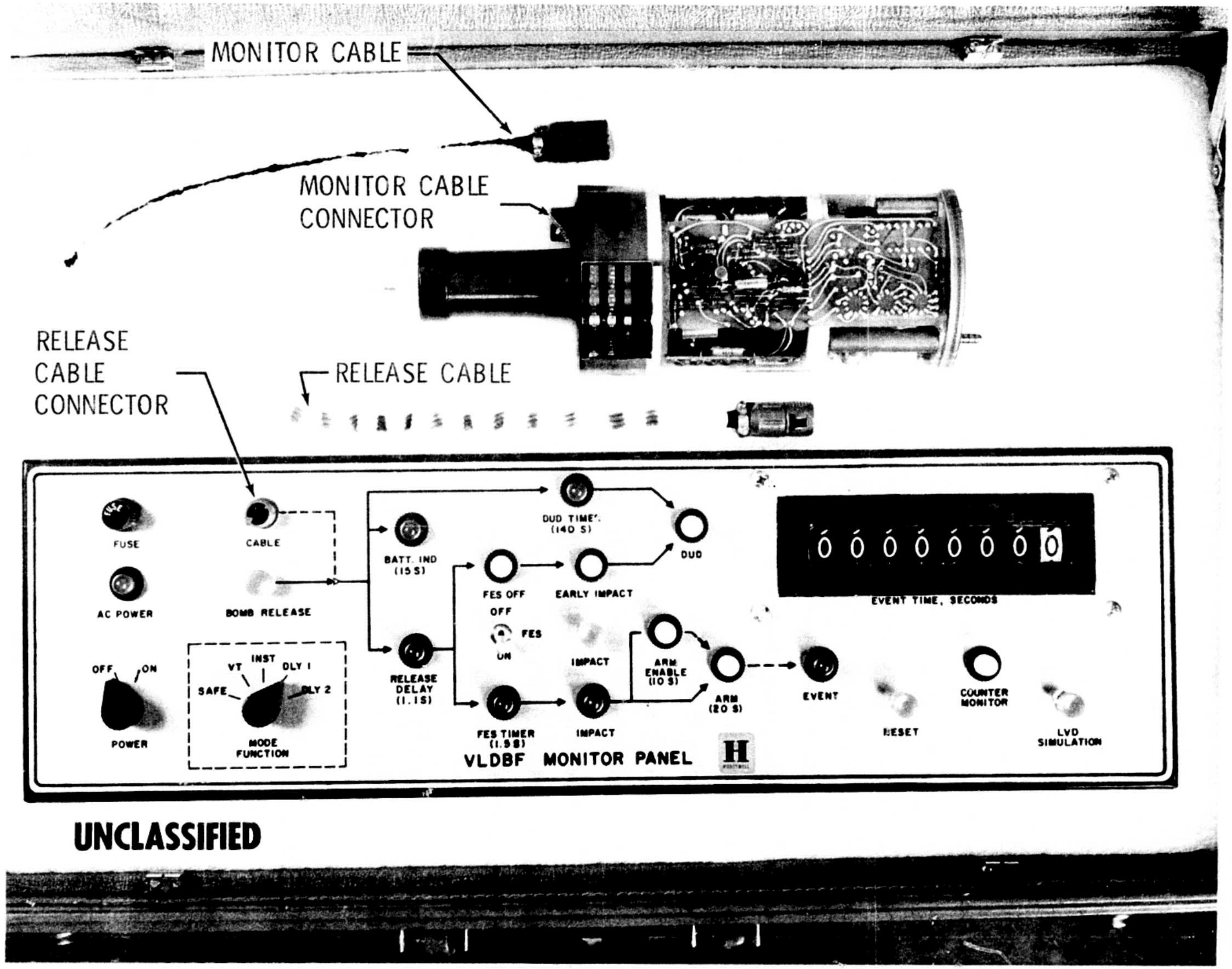


Figure 23. Cockpit-Settable Fuze Demonstration Unit, Showing Monitor Panel Layout

(U) Continued

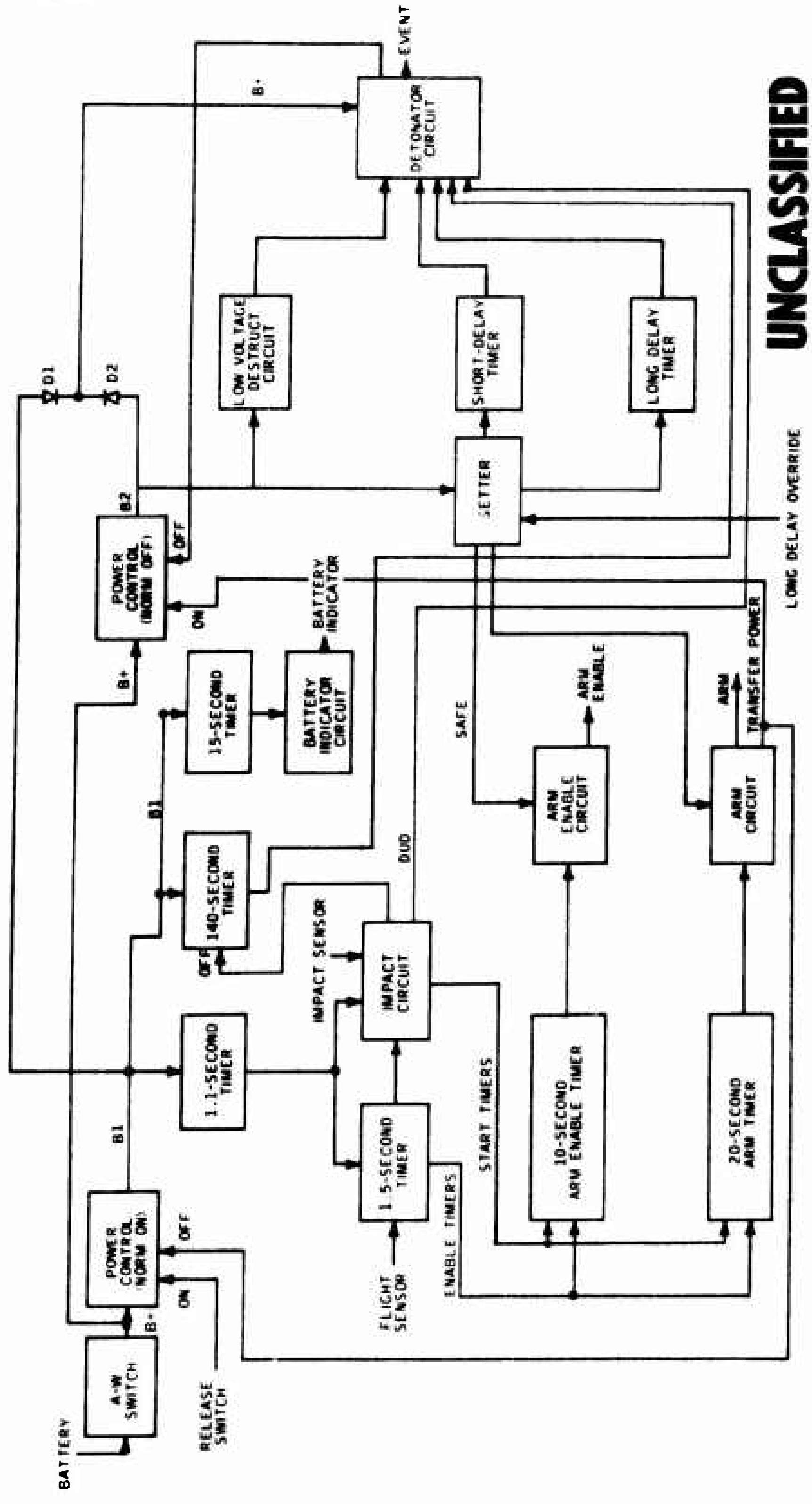
and the mode of operation is selected (by the MODE FUNCTION switch on the monitor panel), the ac POWER SWITCH is turned ON, the RESET pushbutton is pressed (to restore monitor panel circuits), and the BOMB RELEASE pushbutton is pressed (this last action simulates the function of the pickle switch in the cockpit). Now the bomb is "released", and the release cable is disconnected, thus simulating the corresponding breakaway function of an actual bomb release. The flight environment sensor (FES) switch is set to ON and, not less than 1.5 seconds later, the IMPACT pushbutton is depressed, thus simulating the corresponding functions of an actual bomb delivery. (An accidental release can be simulated by leaving the FES switch OFF and pressing the IMPACT pushbutton, the result of which will light the DUD indicator.) At appropriate intervals from activation of the impact simulator, the ARM ENABLE and ARM indicator will be lighted. After the preset delay time has elapsed (as indicated by the EVENT-TIME, SECONDS counter), the EVENT indicator is lighted. A critical decrease in operating voltage before event can be simulated by pressing the LVD SIMULATION pushbutton, in which case the EVENT indicator will be lighted immediately. Tampering with an armed bomb can be simulated by pressing the anti-withdrawal switch on the fuze, which will also result in an event indication immediately.

(U) A demonstration is terminated by either an event or dud indication, at which time power is automatically disconnected from the unit.

1. Functional Description

(U) A functional block diagram of the cockpit-settable fuze is presented in Figure 24. Except for the differences discussed below, the cockpit-settable fuze operates the same as the ground-settable fuze (see description in Paragraph A1).

(U) Application of the operating power is similar to the corresponding function in the ground-settable fuze, except that an additional function was



UNCLASSIFIED

Figure 24. Block Diagram, Cockpit-Settable Fuze

(U) Continued
added; B2 power (and, therefore, all power) is disconnected immediately after an event or dud function. This feature was accomplished by replacing the squib switch of the ground-settable fuze by an electronic power control circuit. Diodes D1 and D2 provide B+ to the detonator circuit whenever the power is on. A manual power control function was incorporated by connecting the anti-withdrawal (A-W) switch in series with the battery and fuze circuits. Note that this arrangement still provides an anti-tamper feature; if the battery is disconnected after the fuze arms, the fuze is evented immediately by an output of the low-voltage destruct circuit.

(U) The arming cycle is the same as the arming cycle of the ground-settable fuze with the following exception: the 1.5-second timer is disabled until the release delay timer has timed out (1.1 seconds from release). This modification permits a clearer demonstration of the function of the flight environment sensor and associated circuits. In an operational cockpit-settable fuze, the 1.5-second timer would be designed for compatibility with the flight environment sensor characteristics and for conformance with system safety requirements. A disable function was incorporated between the impact circuit and the 140-second timer, to turn off the 140-second timer after impact.

(C) The selection of event delays is identical to corresponding functions of the ground-settable fuze. However, for convenience, in demonstrating the model, many of the delay times are shorter than in the ground-settable fuze. Sixteen event delays are available, ranging from 5.3 second to 32 days (see complete range in Table II). A back-up timer was not included in the cockpit-settable fuze design.

2. Electronic Circuits

(U) An electrical schematic of the cockpit-settable fuze is presented in Figure 25. Except for the circuits required to implement the event cycle, the electrical design of the cockpit-settable fuze is similar to that of the

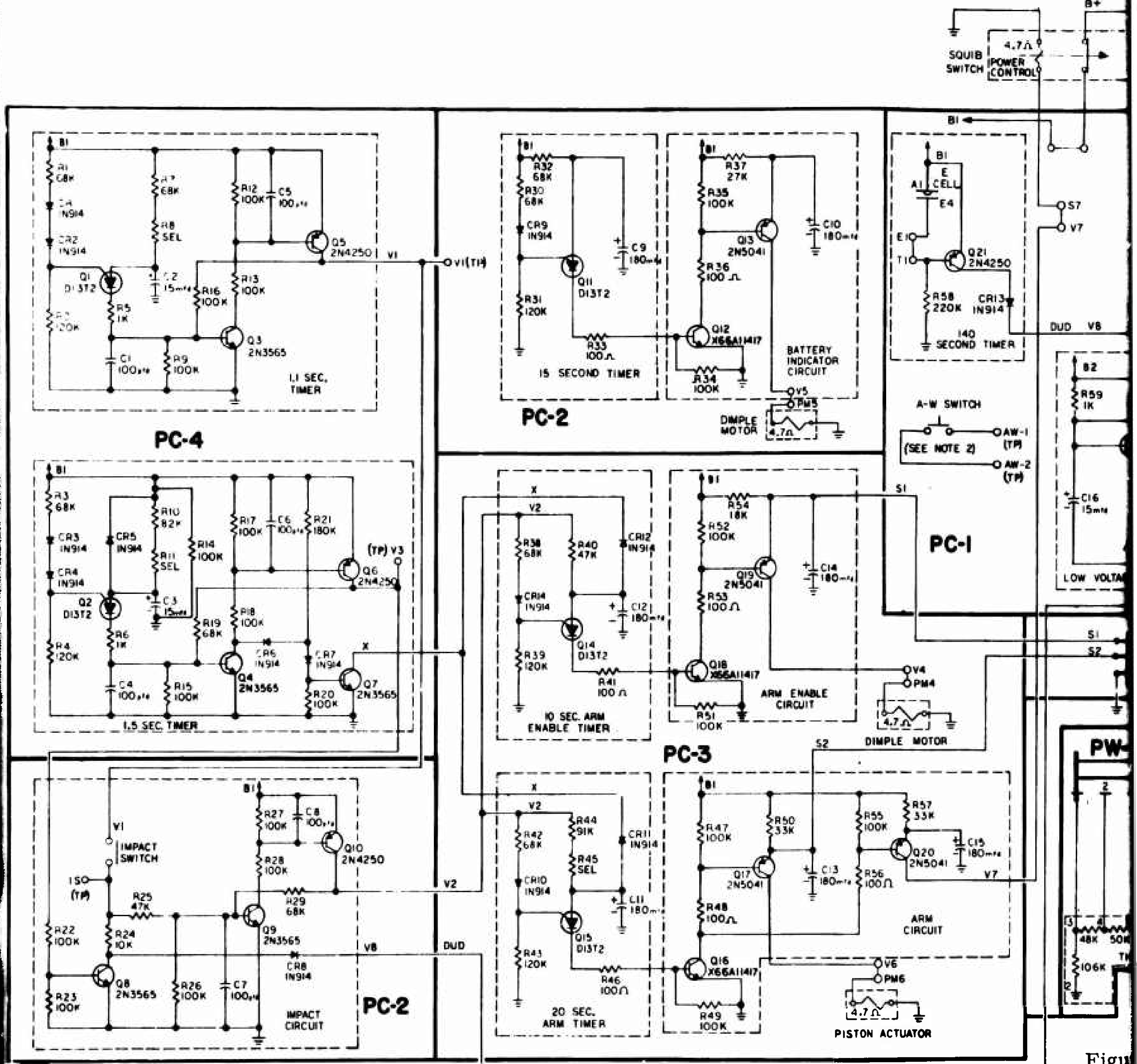
TABLE II. EVENT DELAYS AVAILABLE WITH COCKPIT-SETTABLE FUZE

EVENT DELAY	SWITCH POSITIONS (SEE NOTE 1)				
	TIME SELECTOR SWITCH (SEE NOTE 2)	MODE SELECTOR SWITCH (SEE NOTE 2)		TIME SELECTOR SWITCH	MODE SELECT SWITCH
		SETTING	COLOR		
INST.	N/A	SHORT	SILVER	N/A	2
5.3 SEC.	5.3	MIN.	RED	1	3
		HRS.			
		SEC.			
21.0 SEC.	21			2	
42.0 SEC.	42			3	
1.4 MIN.	1.4		GREEN	4	
5.6 MIN.	5.6			5	
45.0 MIN.	45			6	
1.5 HRS.	1.5		SILVER	7	
3.0 HRS.	3			8	
6.0 HRS.	6			9	
12.0 HRS.		U		10	4
1.0 DAY	U	U		11	
2.0 DAYS	U	U		12	
4.0 DAYS	U	U		13	
8.0 DAYS	U	U		14	
16.0 DAYS	U	U		15	
32.0 DAYS	U	U		16	

NOTES:

CONFIDENTIAL

1. POSITIONS NOTED FOR TIME SELECTOR SWITCH AND MODE SELECT SWITCH CORRESPOND TO POSITION NOTATIONS ON SCHEMATIC DIAGRAM.
2. NOTATION "U" INDICATES THAT SWITCH POSITION IS NOT INDICATED ON MODEL (TO DECLASSIFY THE MODEL), NOR ARE CORRESPONDING CIRCUITS SHOWN IN SCHEMATIC DIAGRAM.



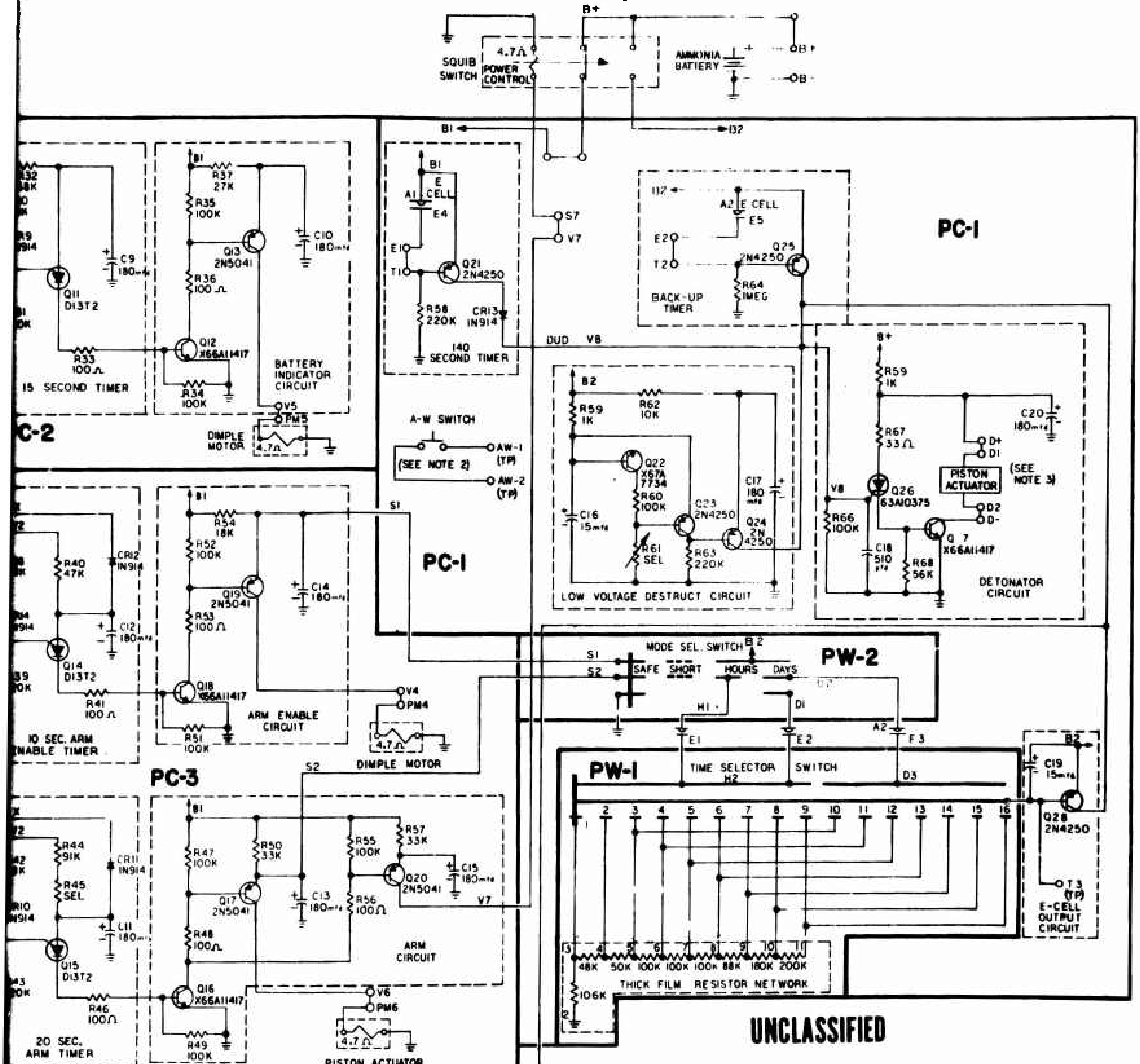
Figu

2. ANTIWITHDRAWAL SWITCH WAS NOT CONNECTED IN DELIVERABLE MODELS. TEST POINTS (AW-1 AND AW-2) WERE PROVIDED TO TEST SWITCH AFTER IMPACT.

. RESISTORS ARE 1/8 W CARBON COMPOSITION.

4. TP - TEST POINT USED TO MONITOR FUZE FUNCTION.

3. PISTON ACTUATOR USED AS EVENT INDICATOR IN PLACE OF DETONATOR IN DELIVERABLE MODELS.



UNCLASSIFIED

Figure 25. Schematic of VLDF (Cockpit-Settable)

TO MONITOR FUZE FUNCTION.
AS EVENT INDICATOR
IN DELIVERABLE MODELS.

(The reverse of this page is blank)

(U) Continued
ground-settable fuze (see circuit descriptions in Paragraph A2). Accordingly, only those circuits which differ from those in the ground settable fuze are discussed below.

(C) Note that only two countdown circuits are shown in Figure 25, whereas three countdown circuits are included in the cockpit-settable fuze. The third countdown circuit, which provides event delays from 12 hours to 32 days (see list in Table 2), is connected to terminals 10 through 16 of the time selector switch and to the output of the pre-set circuit in a configuration similar to that shown for the other two countdown circuits.

(U) The programmable unijunction transistor (PUT) timer concept implemented for the ground-settable fuze was also used in the arming logic of the cockpit-settable fuze to provide short timing functions. Since repeatability was a requirement for the demonstration model of the cockpit-settable fuze, E-Cell timers could not be used. In the cockpit-settable fuze the 140-second timer was implemented with a PUT timer, and the long delay timers were implemented with complementary metal-oxide semiconductor (CMOS) circuits.

(U) The CMOS is representative of a recently developed technology which permits extremely low-power operation of digital circuits. The basic switching element in the circuit is metal-oxide semiconductor (MOS) transistor. The basic difference between an MOS transistor and a standard bipolar transistor is that the current flow through the switching element is controlled by a voltage field rather than by current. Therefore, the input impedance of a MOS is very high (megohms) and the switch can be controlled with very low currents. Although control current is low, the quiescent current can still be relatively high when the transistor is conducting because a resistor is usually used as a load to the MOS transistor. The use of a complementary arrangement of MOS devices in which the load resistor is replaced with a transistor of opposite polarity results in appreciably lowest quiescent power. Interconnecting a number of complementary pairs

(U) Continued

of MOS devices on the same integrated circuit chip provides various logic functions such as AND and OR gates and flip-flops. Due to the relative simplicity of the manufacturing process of MOS devices (as compared to the bipolar process), large circuit arrays can be fabricated on the same chip. For example, the countdown circuits in the cockpit-settable fuze provide a 2^7 countdown (divide by 128) capability in one integrated circuit package. The quiescent current for such a device is less than 10 microamperes at 10 volts. Although a CMOS circuit requires a relatively high transient (switching) current (approximately 1 milliampere), the requirement exists for only a short time, typically 0. 1 microsecond. Therefore, since the switching frequency is less than 1 cps, the total average current requirement is approximately 10 microamperes per 2^7 counter.

a. Electrical Squib and Power Turn-Off Circuit - (U) When B+ (battery) power is initially applied through the A-W switch, neither B1 nor B2 power is connected to the fuze. A positive pulse (developed by pressing the RELEASE pushbutton on the monitor panel) turns on the B1 latching circuit of Q3 and Q4. The detonator circuit also receives B1 power through CR5. When the fuze arms, a positive signal on line V7 turns on Q2, the conduction of which grounds the gate of the latching circuit (collector of Q3) and therefore turns off the B1 latching circuit. At the same time, the V7 signal turns on the B2 latching circuit of Q5 and Q6; thereafter until event, B2 power is applied to the detonator circuit through CR6. When the fuze events, the D-signal grounds the gate of the B2 latching circuit (collector of Q5), the result of which disconnects B2 power from the fuze. Since B1 power is also not available under these circumstances, the fuze operation is terminated.

b. 140-Second Timer - (U) The function of the 140-second timer is the same as the corresponding circuit in the ground-settable fuze circuits. In the cockpit-settable fuze, CR1 and R5 were added to discharge C10 when an impact is simulated. When the IMPACT pushbutton on the monitor panel is pressed, point Y is connected to the collector of Q9 in the impact circuit. The resultant conduction of Q9 grounds line Y when the impact latch is triggered.

c. Short Delay Timer - (U) To achieve an "instantaneous" event, the mode select switch is set to SHORT, the position of which connects B2 power to the base of Q11 (of the output circuit) which, in conducting, triggers the detonator circuit, the result of which is an event shortly after the fuze arms.

(U) A SHORT event can also be achieved by selecting the INST position of the MODE FUNCTION switch on the monitor panel. The override function is achieved with the override relay. In a DLY 1 position, the override relay contacts are open, permitting normal fuze function. Upon pressing the BOMB RELEASE pushbutton when in INST position, voltage is applied to SD terminal of the relay, thus closing the contacts between B2 and V_o lines. Application of B2 at arming will cause "instantaneous" event.

d. Long Delay Timer - (C) The long delay timer consists of the (DC-to-DC) voltage converter, the preset circuit, and the countdown circuits. The voltage converter circuit steps up the B2 voltage to the level required for CMOS circuit operation. The preset circuit established an initial reference for the time base circuit and the conditions the countdown circuits when B2 power is first applied. In accomplishing these functions, the preset circuit forces the reference level in the time base circuit to a zero condition, and sets all stages of the countdown circuits to a logic "0". The time base circuit, which operates at a frequency of 0.38 Hz, provides timing pulses to the countdown circuits (as stated previously, only two of the three countdown circuits are shown on the schematic of Figure 25). The operation of the time base circuit is monitored by amplified Q10, the output of which drives the counter monitor indicator on the monitor panel. The countdown circuits are capable of counting to 32 days.

e. Detonator Circuit - (U) The detonator circuit is functionally the same as the corresponding circuit in the ground-settable fuze. In the cockpit-settable fuze, Q7 was added to provide a turn-off signal to the B1 latching circuit whenever the dud function is simulated. The output of Q7 (D-) also provides event and dud signals to the monitor panel by turning off the B2 latching circuit whenever an event or dud function is simulated.

SECTION VI

TESTING AND EVALUATION

(U) Tests were conducted with a group of first preliminary models (two units) and a group of second preliminary models (three units), primarily to evaluate component survivability and the accuracy of the timing functions. The three second preliminary models were complete fuzes, essentially identical to the 20 deliverable models. The deliverable models were tested both during and after assembly.

(U) Tests were conducted with models of the explosive train to determine the detonator transfer characteristics and to provide a qualitative assessment of safety. (The explosive train components provided with the deliverable models were inert, except that the detonator was replaced by a piston actuator to function as an event indicator.)

(U) A procedure was also prepared for possible use by the Air Force in evaluation of the deliverable models.

A. EVALUATION OF FIRST PRELIMINARY MODELS

(U) The two first preliminary models (designated P1 and P2) were subjected to the following initial evaluations:

- Energy-level requirement for battery firing device (BFD) operation
- Force-vs-deflection measurements of setter switch contacts
- Measurements of force required to operate S&A shutter detent and gag pin
- Measurements of resistances of bridgewires of explosive motors and squib switches

(U) The following environmental tests were performed:

- Transportation Vibration (MIL-STD-331, Test 104)

(U) Continued

- Impact shock as follows:
  - for P1, nose first into hard packed sand at 850 fps
  - for P2, tail first into hard packed sand at 850 fps
- Water immersion to a depth of 50 feet.

(U) After each environmental test, the fuzes were evaluated, as applicable, for the following:

- Physical damage
- Electrical continuity through selector switch contacts
- Water leakage
- Function of electronics
- Function of anti-withdrawal switch

(U) A final test was conducted in which the squib switches were initiated and the signal transfer characteristics were evaluated.

1. Test Results

a. Fuze P1 - (C) The following observations were made for Fuze P1:

- No physical damage was observed that could be attributed directly to the shock caused by impact.
- The BFD functioned correctly (was not actuated by impact shock).
- The plunger of the anti-withdrawal switch functioned correctly after the impact shock (the plunger was held down during the test to simulate a normal fuze operation).
- Moisture was observed in the BFD, the S&A shutter cavity, and the electronic module cavities of the setter. One pinhole was found in a bellows seal; the remaining leaks were through the setter housing.

b. Fuze P2 - (C) The following observations were made for Fuze P2:

- The BFD functioned correctly (was not actuated by impact shock).

(C) Continued

- The retainer ring broke off at impact (as intended); the remainder of the fuze body was not damaged.
- The plunger of the anti-withdrawal switch (which was not held down during the impact test) was jammed. An X-ray analysis revealed that potting material entered the switch housing and jammed the plastic pushbutton.
- The S&A housing column (fabricated of soft aluminum) deformed at impact.
- One of the eccentric pin-to-bellows seal bonds failed.
- Moisture was observed in the BFD, the S&A shutter cavity, and the electronic module cavities of the setter.

2. Conclusions

(U) As a result of the evaluations of fuzes P1 and P2, the following assessments were made for improvements in design and fabrication:

- To ensure impact survival, the S&A housing material must be fabricated of steel or some other material of equivalent strength.
- The anti-withdrawal switch must be sealed more effectively against the entry of potting material.
- A more effective bond is required between the eccentric pin and bellows seal.
- A testing procedure is required to ensure against leakage through the bellows seal and setter housing.

B. EVALUATION OF SECOND PRELIMINARY MODELS

(U) The three second preliminary models (designated P3, P4, and P5) were subjected to the following initial evaluations:

- Energy-level requirement for BFD operation
- Force-vs-deflection measurements of setter switch contacts
- Measurements of force required to operate setter knob detents
- Operation of safe/arm indicators
- Leakage resistance of selector switch assemblies.

(U) After assembly, the following environmental tests were performed:

- Transportation Vibration per MIL-STD-331, Test 104 (for fuzes P3 and P4)
- Aircraft Vibration per MIL-STD-810 (for fuze P5)
- Impact shock as follows:
  - for P3, nose first into hard packed sand at 850 fps
  - for P4 and P5, tail first into hard packed sand at 850 fps
- Water immersion to a depth of 50 feet.

(U) For each fuze, the battery was initiated and the fuze was subjected to the impact test. After recovery, the event times were measured (each fuze was set for a delay of 1 hour). Then the battery was disconnected and the functions of the remaining long delay timers and back-up timers were evaluated. Finally the water immersion test was performed to check for leakage.

1. Test Results

a. Fuze P3 - (C) The following observations were made for Fuze P3:

- No physical damage was observed that could be attributed directly to the shock caused by impact.
- A relatively low insulation resistance of 50K ohms was measured between the anti-withdrawal switch contacts and the case.
- Moisture was observed in the BFD, the S&A shutter cavity, the setter housing, and the anti-withdrawal switch.

(U) The results of the timing tests of Fuze P3 are summarized in Table III.

TABLE III. RESULTS OF TIMING TESTS OF FUZE P3

ITEM	SET TIME	MEASURED TIME
BATTERY INDICATOR TIMER	N/A	14 SECONDS
EVENT TIMER	1 HOUR	57 MINUTES
EVENT TIMER	18 HOURS	19 HOURS, 15 MIN.
EVENT TIMER	144 HOURS (6 DAYS)	153 HOURS, 19 MIN.
BACK-UP TIMER	72 HOURS	70 HOURS, 58 MIN.
		CONFIDENTIAL

b. Fuze P4 - (C) The following observations were made for Fuze P4:

- The S&A housing column was slightly deformed at impact, but the unit armed properly.
- The plunger of the anti-withdrawal switch was bent at impact; therefore, the switch jammed.
- Moisture was observed in the S&A shutter cavity and the setter housing.

(U) The results of the timing tests of Fuze P4 are summarized in Table IV.

TABLE IV. RESULTS OF TIMING TESTS OF FUZE P4

ITEM	SET TIME	MEASURED TIME
BATTERY INDICATOR TIMER	N/A	14.5 SECONDS
EVENT TIMER	1 HOUR	1 HOUR, 45 SEC.
EVENT TIMER	18 HOURS	18 HOURS, 15 MIN.
EVENT TIMER	144 HRS. (6 DAYS)	152 HOURS, 19 MIN.
BACK-UP TIMER	72 HOURS	69 HOURS, 43 MIN.
		CONFIDENTIAL

c. Fuze P5 - (C) The following observations were made for Fuze P5:

- The S&A housing was slightly deformed at impact, but the unit armed properly.

- The plunger of the anti-withdrawal switch was jammed closed by potting material, causing the fuze to event at arming.

- The retainer ring broke off at impact (as intended); the remainder of the fuze body was not damaged.

- Moisture was observed in the BFD, S&A shutter cavity, setter housing, and anti-withdrawal switch.

(U) The results of the timing tests of Fuze P5 are summarized in Table V.

TABLE V. RESULTS OF TIMING TESTS OF FUZE P5

ITEM	SET TIME	MEASURED TIME
BATTERY INDICATOR TIMER	N/A	13.2 SECONDS
ARM ENABLE TIMER	N/A	9.5 SECONDS
ARM TIMER	N/A	19.0 SECONDS
EVENT TIMER	1 HOUR	1 HOUR, 9 MIN.
		CONFIDENTIAL

Note: Further testing of the event timer could not be continued because the jammed (shorted) anti-withdrawal switch caused the battery to fail.

2. Conclusions

(C) The following conclusions are based on the evaluations of Fuzes P3, P4, and P5:

- The battery indicator timer, the arm enable timer, and the arm timer functioned correctly.

- The E-Cells performed as follows:
  - average error, 5.5%
  - greatest error, 15.0%
  - least error, 1.25%

(U) Continued

- A slight deformation of the S&A housing column does not appear to affect operation.

- Water leakage into the S&A shutter cavity and the battery firing device is not detrimental to fuze operation on a short-term basis.

- Water leaked into the setter housing through cracks in the setter housing. The cracks occurred at impact.

- The plunger of the anti-withdrawal switch must be strengthened.

C. EVALUATION OF DELIVERABLE MODELS

1. <u>Evaluation Procedure</u>

(U) The 20 deliverable models were subjected to the following pre-assembly tests:

- Energy-level requirement for BFD operation

- Force-vs-deflection measurements of setter switch contacts

- Measurements of force required to operate S&A shutter detent and gag pin

- Measurements of resistance of bridgewires of explosive motors and squib switches

- Leakage resistance test

(U) After the fuzes were assembled and wired, the following tests were performed:

- Measurements of force required to operate setter knob detents

- Measurement of cold battery voltage

- Measurements of resistances of bridgewires of explosive motors and squib switches

(U) After the setters were potted into the containers, the electronic circuits were checked at ambient, 165°F, and -65°F. Also, the cold voltage of the batteries and the resistances of the explosive motors and squib switches were checked.

(U) The explosive motors in the S&A mechanisms were checked after the S&A mechanisms were assembled. After final assembly and potting, the explosive motors were checked again.

2. Evaluation Results

(U) The results of the evaluations of the 20 deliverable models are summarized in Table VI.

D. EXPLOSIVE TRAIN EVALUATION

(U) The explosive trains supplied with the 20 deliverable models were inert. However, tests were conducted to qualitatively evaluate the explosive train design configuration. These tests and the results obtained are discussed in the following paragraphs.

1. Detonation Transfer (Detonator to Lead)

(C) Bruceton techniques were used to evaluate the detonation reliability of the detonator and lead. The test results showed a reliability level of 99.9 percent at a confidence of 95 percent.

(U) Initial testing was done with simple air gaps, but the detonator was able to initiate the lead over such relatively great distances that this approach was abandoned. Furthermore, when testing over long air gaps, the probability of hitting the lead with the full output of the detonator decreases significantly, and the probability itself is difficult to establish.

(U) To eliminate the variable associated with testing over long air gaps, the air gap was decreased and, to attenuate the detonator output at the lead, a cellulose acetate (CA) barrier was inserted in the gap. The detonator-to-lead gap was maintained at 0.085 inch, which corresponds to the tactical design. Tests were conducted with CA barriers of various thicknesses.

TABLE VI. RESULTS OF EVALUATION OF 20 DELIVERABLE MODELS

ITEM	RESULTS
SQUIB SWITCHES AND EXPLOSIVE MOTORS	ALL UNITS CHECKED OUT PROPERLY.
SELECTOR SWITCHES	CONTACTS SHORTED IN HOURS POSITION, BETWEEN B2 AND GROUND (7 FUZES), DUE TO INADEQUATE CLEARANCE BETWEEN SWITCH PADS ON PC BOARDS.
SETTER DIALS	BINDING IN HIGH-TERMPERATURE ENVIRONMENTS (2 FUZES) DUE TO INADEQUATE CLEARANCE BETWEEN SETTER DIALS.
IMPACT SWITCH	IMPACT DUD CIRCUITS OF 2 FUZES FAILED AT -65°F (BATTERY OUTPUT WAS 3.5 VOLTS.
LOW-VOLTAGE DETECTOR	DETECTOR FAILED AT -65°F IN 8 FUZES.
BACK-UP TIMER	FAILED TO FUNCTION AT -65°F IN 7 FUZES (BATTERY OUTPUT WAS 2.8 VOLTS). ONE FAILURE CAUSED BY OPEN BASE RESISTOR.
1.5-SECOND TIMER	FAILED TO FUNCTION AT -65°F IN 1 FUZE.
140-SECOND TIMER	FAILED TO FUNCTION AT -65°F IN 1 FUZE (BATTERY OUTPUT WAS 3.5 VOLTS).
EVENT TIMER	FAILED TO FUNCTION IN 1 FUZE IN A SHORT-DELAY TEST OF -65°F.

UNCLASSIFIED

(U) The tests indicated a 50-percent point with a CA barrier of 0.0264 inch, with a standard deviation of 0.0019 inch. Calculations based on these data showed that, if the CA barrier were removed, thus resulting in an air gap of 0.085 inch, (as specified for the design), the reliability of detonation transfer would be 99.9 percent at a confidence level of 95 percent.

2. Detonation Transfer (Lead to Booster)

(U) These tests were conducted across uninterrupted air gaps, which were varied in accordance with the Bruceton technique. The 50-percent point was achieved at a gap width of 2.20 inches, with a standard deviation of 0.070 inch. Thus, in the tactical design, in which the air gap is more than 28 standard deviations smaller than the gap defined by the 50-percent point, an exceedingly high reliability of detonation transfer should be achieved. On the basis of these results, it is recommended that the lead be scaled down.

3. Static Detonator Safety and Progressive Arming

(U) Detonator-to-lead center line-to-center line displacements were varied in accordance with the Bruceton technique. The leads were confined in Nylafil shutters. The center line-to-center line displacement for the 50-percent fire point was determined to be 0.146 inch, with a standard deviation of 0.005 inch. The 50-percent point corresponds to an overlap of approximately 0.060 inch, or about 0.6 of a detonator diameter.

(U) These results, all of which were obtained at room temperature, indicate a definite capability for compliance with MIL-STD-331, Test 115, Static Detonator Safety. This conclusion is also supported by the results of the tests conducted at edge-to-edge displacements of 25, 50, and 100 mils; the test results showed minimum lead deformation. An edge-to-edge displacement of 100 mils is recommended.

4. Barrier Effectiveness

(U) In the VLDF design developed during Phase II, the detonator output, when the detonator is in the safe (out-of-line) position, is interrupted from the CH-6 booster by a 0.375-inch Nylafil barrier. Tests conducted during the contract verified the effectiveness of this design; the maximum penetration of the 0.375-inch thick Nylafil barrier by the microdetonator output was approximately 0.070 inch. The barrier design was based on the following results obtained in tests of explosive trains of designs similar to the VLDF design.

(U) For the air gap specified for the VLDF explosive train, the 50 percent initiation point for the HMX lead is reached when the air gap is interrupted with a cellulose acetate barrier of 0.052 inch, with a standard deviation of 0.004 inch. For a PBXN-5 lead, the barrier thickness is 0.026 inch and the standard deviation is 0.002 inch. Thus, the probability of the initiation of either an HMX or PBXN-5 lead by the output of an out-of-line microdetonator across an air gap interrupted by a 0.375-inch cellulose acetate barrier lies many deviations lower than the standard deviation defined at the 50 percent initiation point. Since CH-6 is less sensitive to initiation than either HMX or PBXN-5, and also because Nylafil has a higher density and strength than cellulose acetate, the probability of initiating a CH-6 booster through the 0.375-inch Nylafil interrupter is extremely low.

E. RECOMMENDED AIR FORCE EVALUATION PROCEDURE

(U) The following procedure was developed for possible use by the Air Force in evaluating the 20 deliverable models of the ground-settable fuze supplied during the VLDF Phase II contract.

> NOTE: Inert explosive train components were supplied with the deliverable fuzes. Also, all explosive components in the deliverable ground-settable fuzes are physically located to insure that the explosive effects of these devices will not in any way be propagated outside the fuze container.

(U) The recommended evaluation procedure is as follows:

1) Condition fuze in temperature, humidity, and vibration environments, as desired.

2) Set fuze for desired event timer (adjust setter dials on front face of fuze).

NOTE: Steps 1 and 2 can be performed in either order.

3) Connect lanyard to battery firing device. Remove battery firing device safe pin. Insert fuze into either nose or tail fuze well of M117 or MK 82 bomb.

4) Initiate fuze battery by applying a pull force on lanyard. The pull force would normally be applied as the bomb is released from the delivery aircraft.

NOTE: The fuze must be initiated at least 1.1 seconds before an impact shock is experienced. Also, to prevent dudding, a shock of at least 80 g's must be experienced within 120 seconds from battery initiation.

5) Subject fuze to environmental flight test shock conditions.

6) After fuze recovery, connect electronic test equipment to appropriate terminals on rear plate of S&A mechanism (located under inert booster). When a proper fuze event occurs, a voltage pulse with a peak of at least 2.0 volts and a duration of 1 millisecond will be measured across the detonator terminals.

F. AIR FORCE EVALUATION

(C) Air Force evaluation began with drop tests of the ground-settable fuze in M117 bombs. Two bomb configurations were used, clean and retarted, with the MAU-91 fin assembly. The initial results of these tests indicate that the fuze functioned within specifications. The fuzes tested all armed properly and evented per specification requirements when set for delays of 1 - 2 1/2 days. The units were than reset for the 30-day delay period to evaluate the longest delay setting. Again the units evented within specifications.

(C) The flight environmental sensor was monitored during the drop with flash bulb units to indicate operation. Test results on these units indicate that they operated as intended, detecting free fall ballistic flight.

SECTION VII

SAFETY AND RELIABILITY

(U) A safety analysis was conducted to define the conditions under which unintentional event could occur in the use of the ground-settable Very Long Delay Fuze developed during Phase II. Reliability estimates were also made for the complete fuze and for individual circuits.

A. SAFETY ANALYSIS

(U) The safety analysis was conducted in accordance with MIL-STD 1316. The object of the analysis was the definition of accidents and/or failures which could lead to or be the direct cause of unintentional event conditions. Unintentional event conditions were judged by the Air Force criteria for the existence of a hazardous condition, i.e., "a hazardous condition exists when two or less simultaneous accidents and/or defects can result in unintentional event".

(U) Each of the normal operating modes of the fuze was analyzed for the presence of hazardous conditions. These operating modes are as follows:

Mode 1 - Event during installation and setting, or event during handling, transportation, or storage of fuzed bombs.

Mode 2 - Event on ramp, taxiway, runway, or carrier deck during loading, landing, or taking off.

Mode 3 - Event on aircraft.

Mode 4 - Event shortly after normal release, prior to 20 seconds after battery initiation.

Mode 5 - Event within 20 seconds after impact.

Mode 6 - Event on the ground after jettison or accidental drop.

Mode 7 - Event at other than set time.

(U) The results of the safety analysis conducted on the above modes of operation were reviewed for fuze changes which could improve the fuze safety. These results are summarized below along with improvements which should be considered in future development programs:

NOTE: Hazard conditions are listed only once and may occur in other modes of operation. Conditions are listed for the earliest operational mode in which they could be encountered.

Mode 1 Safety - In this mode, a hazardous condition could exist if the fuze were accidentally initiated and the gag in the safing and arming mechanism were missing.

Possible Improvement: This hazard condition can be prevented by the addition of a spring loading feature to prevent the arming shutter from moving into the armed position (without being driven there by the arming piston actuator) if the gag is missing.

Mode 2 Safety - A hazardous condition could exist in this mode if the bomb were accidentally dropped during landing or takeoff. If the fuze were then initiated on impact, by a snagged lanyard or impact initiated battery, broaching of the bomb could result in a live munition.

Possible Improvement: Electrical initiation of the fuze would prevent this possible hazard condition by isolating the flight sensor until the fuze was intentionally initiated.

Mode 3 Safety - A hazardous condition could exist in this mode if the fuze were accidentally initiated during flight and certain electronic components were defective, thus bypassing the impact circuits. If the aircraft then went into a series of extreme pullups or dives which could function the flight sensor, the munition would event at the preset time.

Possible Improvement: Electrical initiation of the fuze would eliminate this hazard condition.

Mode 4 Safety - There are not hazard conditions unique to this mode.

Mode 5 Safety - This mode occurs after impact. For this reason many safety features have already been "spent" and removed from the active system. If the fuze is set for short delay and the arming timer circuits are defective, the bomb could event 10 seconds after impact. If both the arming timer and the arm enable circuits were defective, the bomb could event on impact.

Possible Improvement: While the hazard is considerably less during this mode of operation, delaying the function of the arm enable circuits until just before arming would increase fuze safety.

Mode 6 Safety - Mode 6 safety conditions are the same as the Mode 2 conditions listed above.

Mode 7 Safety - During this mode of operation, the fuze is armed waiting for "event" by one of several event circuits. A defect in any one of these circuits could event the bomb.

Possible Improvement: Bomb fuze safety cannot be improved at this point without unduly jeopardizing functional reliability.

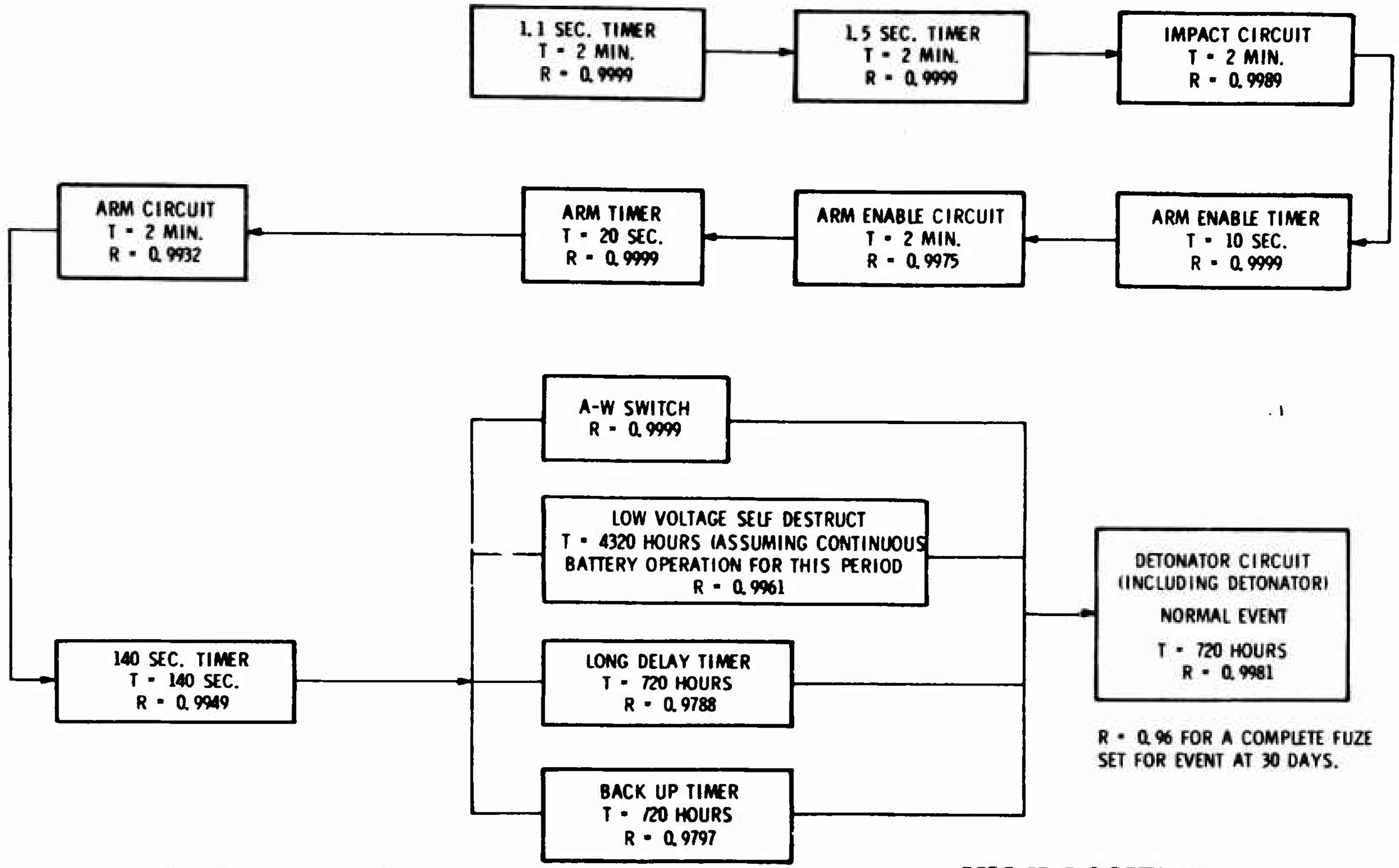
B. RELIABILITY

(C) The reliability estimates that were calculated for the various sections within the Very Long Delay Fuze are presented in Figure 26. The estimates were based on an average operating temperature of 25° C. The reliability estimate of 0.96 for the complete fuze was based on an event-time setting of 30 days.

(U) Data from MIL-HBK-217A were used as available in calculating the reliability estimates. Where data were not available from MIL-HBK-217A, reliability estimates were based on failure rates developed by either the contractor or by vendors.

(U) The effects of impact on component reliability were not considered in the reliability calculations because of a lack of sufficient data. For the same reasons, the 2-cell ammonia battery and the flight environment sensor were not included in the calculations. Continued application of engineering on the ammonia battery is expected to yield a design capable of meeting VLDF reliability requirements. This is based on a demonstrated reliability of over 98% for other ammonia batteries in current production. The reliability estimate calculated for the 140-second timer, 0.9949, was based on the probability of an early time-out of the E-Cell (a late time-out or a failure to time out would not degrade the functional reliability).

(U) The reliability of the battery indicator circuit was not included in the calculation of the reliability estimate for the complete fuze, since two or more components of the battery indicator circuit must fail before the



T - MAXIMUM OPERATION TIME

R - RELIABILITY OF INDIVIDUAL SECTION

UNCLASSIFIED

Figure 26. Reliability Diagram

(U) Continued

reliability of the fuze would be degraded. The reliability of the complete fuze was calculated from the reliabilities of each of the circuits shown in Figure 26.

SECTION VIII
CONCLUSIONS

(U) The technical work performed during Phase II of the Very Long Delay Fuze development program has resulted in the following conclusions.

A. DESIGN FEASIBILITY

(C) Feasibility was established for a bomb fuze design with a manually-selectable event time ranging from an event at arming to an event 30 days after arming. Laboratory and field tests demonstrated that all of the fuze components have a definite potential for surviving the impact environment of a 750-pound general purpose bomb and functioning properly thereafter. Additional development and testing is required to improve the impact resistance of the setter. Accelerated life tests showed that the components would be capable of functioning properly after 10 years of storage.

(U) Feasibility was also demonstrated (by a special model designed for the purpose) for the use of electronic techniques to override the selection of a long-delay time and implement the 20-second event time from the cockpit. It was also shown that low-power electronic circuits could be used to provide the required range of event times, as well as other control functions in the fuze.

B. SAFETY

(U) All safety features of the ground-settable fuze have demonstrated a capability to meet most of the requirements of MIL-STD-1316.

(U) Tests of the explosive train demonstrated that all components of the explosive train have a capability to meet the safety requirements of MIL-STD-331, Test 115.

(U) Development tests demonstrated that the battery firing device cannot be functioned by any of the environments characteristic of a jettison safe release.

C. RELIABILITY

(C) Calculations showed that the reliability with which the fuze would event at the predetermined event time (± 20 percent) would be 96 percent.

D. TIMER CHARACTERISTICS

(C) Functional tests of the E-cell timers used in the ground-settable fuze showed an accuracy of at least ±20 percent of the total delay time. Design simplicity and relative economy recommend the E-cell for delay fuze applications.

(C) Feasibility was demonstrated for the use of complementary metal-oxide semiconductor (CMOS) circuits in the cockpit-settable fuze. The current and voltage requirements were shown to be 30 microamperes and 3 - 4 volts, respectively. A potential accuracy of ±5 percent was indicated.

E. FLIGHT ENVIRONMENT SENSOR

(U) The mercury-switch flight environment sensor was shown to be capable of sensing the free-fall flight of a weathercocking bomb utilizing monitoring periods of up to 1.5 seconds.

F. BATTERY

(U) Feasibility was demonstrated for the use of a reserve ammonia battery for the basic power source in the ground-settable fuze. Tests have shown this battery to be capable of meeting the storage and operational requirements specified for the Very Long Delay Fuze.

SECTION IX

RECOMMENDATIONS

(U) The following recommendations are made for Air Force consideration in planning future development of the Very Long Delay Fuze.

A. DESIGN REVIEW

(U) A design review should be conducted for the purpose of comparing the VLDF specifications against current operational requirements. At least the following design characteristics should be reviewed:

- Minimum drop time
- Maximum drop time
- Minimum impact velocity
- Maximum impact velocity
- Methods of fuze initiation
- Anticipated impact surface conditions
- Use of contact-burst option versus a delay-burst option
- Number of delay settings required
- Delay accuracies
- Use of an anti-withdrawal device versus an anti-disturbance device
- The implications and constraints imposed by the addition of a target-activated module to the basic fuze.

(U) The results of this review should be used as a basis for evaluating the current VLDF specification.

B. TIMER

(C) For Fuzes with a delay accuracy requirement of ±20 percent or less, consideration should be given to the continued use of E-cell timers. For fuzes with a delay accuracy requirement of better than ±20 percent, consideration should be given to the use of CMOS timers.

(U) On the basis of the results achieved with the demonstration model of the cockpit-settable fuze, further development of a self-checking CMOS timer concept for use in long delay fuzing applications is strongly recommended, even though this concept is not incorporated in the Very Long Delay Fuze.

C. S&A MECHANISM

(U) Further development of the shutter-type S&A mechanism incorporated in the ground-settable fuze is recommended. Consideration should be given to simplifying the mechanical design through the use of a shorter arming stroke, which was shown to be possible during Phase II.

D. ENVIRONMENT SENSOR

(U) If the design review indicates that event upon impact is not required, consideration should be given to the replacement of the current flight environment sensor with a terminal environment sensor. This type of sensor could be designed to initiate arming only after sensing the impact environment characteristic, change of velocity, of an intentional drop; thus the operational safety of the fuze would be increased.

(U) On the basis of the results achieved during this program, consideration should be given to the continued development of the mercury-type flight environment sensor.

E. ELECTRONIC FUZING

(U) Consideration should be given to the further development of electronic control circuits of the type incorporated in the ground-settable fuze and cockpit-settable fuze.

(The reverse of this page is blank)

CONFIDENTIAL

Security Classification

DOCUMENT CONTROL DATA - R & D

(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)

1. ORIGINATING ACTIVITY (Corporate author) Honeywell Ordnance Division 600 Second Street North Hopkins, Minnesota 55343	2a. REPORT SECURITY CLASSIFICATION Confidential 2b. GROUP 4

3. REPORT TITLE

DESIGN AND DEVELOPMENT OF VERY LONG DELAY FUZE (PHASE II) (U)

4. DESCRIPTIVE NOTES (Type of report and inclusive dates)

Final Report March 1968 through December 1968

5. AUTHOR(S) (First name, middle initial, last name)

W. L. Aschenbeck

6. REPORT DATE	7a. TOTAL NO. OF PAGES	7b. NO. OF REFS
April 1969	102	None

8a. CONTRACT OR GRANT NO. F08635-68-C-0068	9a. ORIGINATOR'S REPORT NUMBER(S)
b. PROJECT NO.	
c.	9b. OTHER REPORT NO(S) (Any other numbers that may be assigned this report)
d.	AFATL-TR-69-59

10. DISTRIBUTION STATEMENT In addition to security requirements which must be met, this document is subject to special export controls and each transmittal to foreign governments or foreign nationals may be made only with prior approval of the Air Force Armament Laboratory (ATWB), Eglin AFB, Florida 32542.

11. SUPPLEMENTARY NOTES Available in DDC	12. SPONSORING MILITARY ACTIVITY Air Force Armament Laboratory Air Force Systems Command Eglin Air Force Base, Florida 32542

13. ABSTRACT

(C) A design was developed to demonstrate the feasibility of a ground-settable Very Long Delay Fuze for use in air-delivered bombs and mines with standard fuze wells, and which is capable of eventing the munition at a preselected time which is selected from a range of event times. The delay range extends from 20 seconds to 30 days after impact, and the delay is selected before take-off. Laboratory tests of complete developmental models demonstrated that the fuze was capable of functioning properly after an impact environment characteristic of the delivery profile of a 750-pound general purpose bomb. Safety features were developed to comply with MIL-STD-1316. The explosive train was developed to meet the requirements of MIL-STD-331, Test 115. The fuze is powered by a reserve ammonia battery (output of 2.8 to 4.5 volts). A fuze model similar in physical and functional characteristics to the ground-settable fuze was developed to demonstrate the feasibility of using the fuze with an AN/AWW-4 Fuze Function Control Set for the purpose of selecting an event time from the cockpit. The cockpit-settable capability was demonstrated successfully, along with the use of complementary metal-oxide semiconductor (CMOS) circuits for timing functions. It was shown that the use of CMOS circuits would provide a fuze of greater accuracy than could be achieved through the use of E-cells.

DD FORM 1 NOV 65 1473 REPLACES DD FORM 1473, 1 JAN 64, WHICH IS OBSOLETE FOR ARMY USE.

CONFIDENTIAL

Security Classification

14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
Ground settable						
Cockpit settable						
CMOS Circuits						
E-cell						